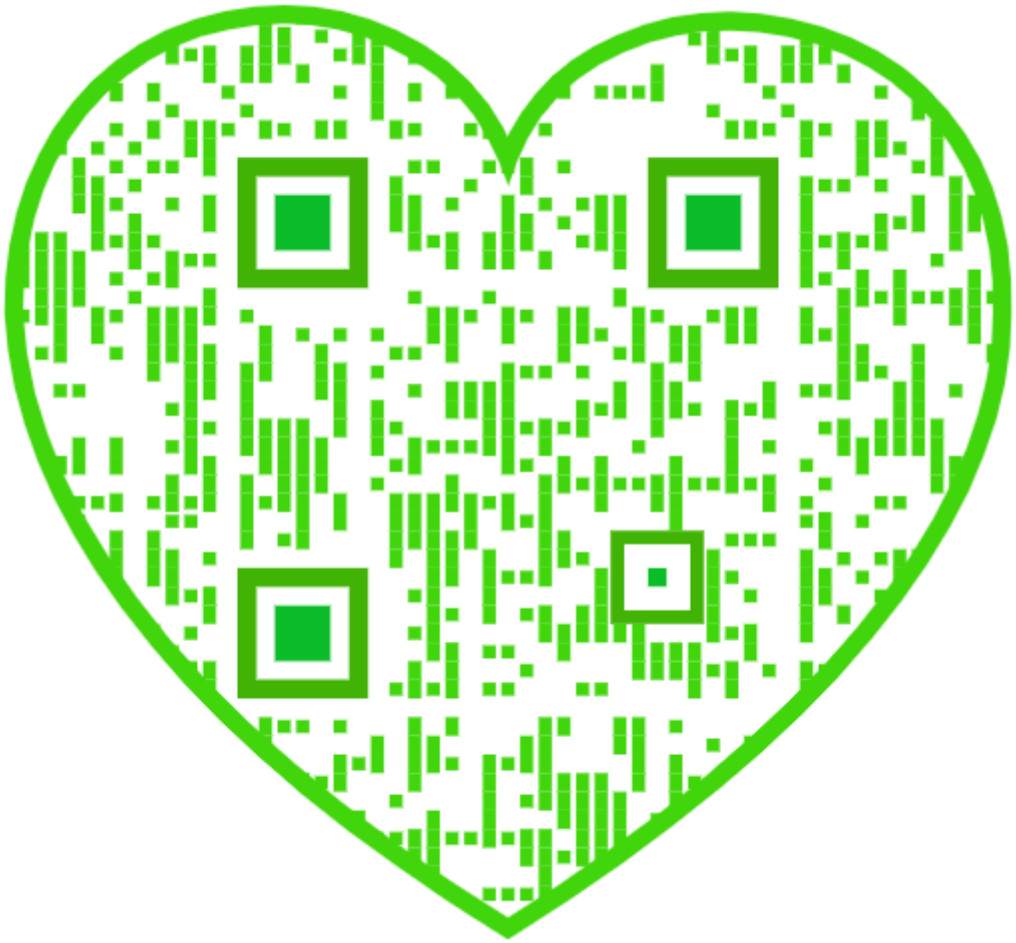

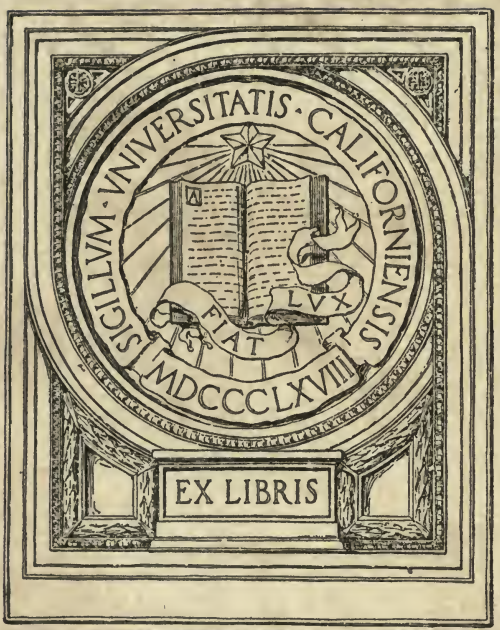

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MILITARY HYGIENE AND SANITATION

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MILITARY HYGIENE AND SANITATION

BY

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WITH DIAGRAMS

LONDON

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AND MANY OTHER OFFICERS NOW FORGOTTEN, WHO IN THE PAST WITH INADEQUATE MEANS EFFECTED SO MUCH FOR THE HEALTH AND WELL-BEING OF THE BRITISH SOLDIER, IN THE HOPE THAT WE, THEIR BETTER-EQUIPPED SUCCESSORS OF THE PRESENT DAY, MAY, BY FOLLOWING THEIR EXAMPLE, ACHIEVE EVEN BETTER RESULTS, SINCE WE CANNOT HOPE TO SURPASS THEIR MERITS

PREFACE

This short treatise on "Military Hygiene and Sanitation" is founded on the lectures delivered by me while Professor of Hygiene at the Royal Army Medical College.

I have not attempted to deal in detail with all the problems of hygiene, and in particular I have omitted—as, for instance, in the question of house drainage—those which are liberally treated in the ordinary textbooks.

In considering the prevention of infectious diseases, also, I have limited myself to those which are most important in war. I have not therefore discussed such ailments as Malta fever and Tuberculosis, for instance, with which the army is concerned mainly in peace-time, under conditions not differing materially from those which confront the Medical Officer of Health in civil practice.

I have to acknowledge much kind assistance from Captain N. Dunbar Walker, Royal Army Medical Corps, who has helped me greatly with suggestions and in the preparation of some of the plates.

I have, further, to thank the Editors of the Journals of the Royal Army Medical Corps and the Council of the Royal Sanitary Institute for permission to make use of a

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number of blocks which had previously appeared in the Journals in question. The lower part of Fig. 5 is copied from an illustration in "Royal Army Medical Corps Training" (1911), and the permission of the Controller of His Majesty's Stationery Office has been obtained for its use.

C. H. M.

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MILITARY HYGIENE AND SANITATION

CHAPTER I

INTRODUCTORY

Man aims at the prevention of disease by the study of the science of hygiene and the practice of the art of sanitation. Strictly speaking, hygiene and sanitation should concern themselves with the prevention of all diseases, but in practice certain ailments are excluded from their purview. They deal, in fact, only with those diseases which are due to causes originating definitely outside the body, which are, in fact, the result of the interaction between the body of man and his surroundings, whether natural or artificial. Certain ailments—for instance, the so-called "diatheses," and the different new growths, malignant or innocent—are at present excluded from this list, though this by no means implies that at some future date they may not be, as a result of greater knowledge, added to it.

We may, in fact, say that hygiene is the science whereby man studies the physical effect on himself of his surroundings; sanitation the art by which he tries to accommodate himself to these surroundings. The distinction between the science and the art is of considerable significance. Hygiene, being a science, is, like all other sciences, ruled by a code of laws which are everywhere and immutably true. This code consists of laws excerpted from among those of physiology which govern the internal economy of man's body, and those of the various natural sciences which regulate the nature and behaviour of his surroundings. On the other hand, sanitation, being an art, is, like all other arts, guided in its

practice by rules which, though founded originally on the laws of hygiene, vary indefinitely with time and place, with the age, sex, and occupations of the population in question, and with a thousand other considerations of practicability and social polity with which hygiene is in no way concerned. This distinction may be illustrated by two very simple examples.

It is an inevitable law of nature that all dead organic matter shall ultimately be oxidized into the simple forms represented by the oxides of (principally) carbon, hydrogen, and nitrogen. This law, in so far as it concerns the surroundings of man—that is, the waste products of his existence, his excreta, remnants of food, and other débris, the dead bodies of his neighbours and his domestic animals—is excerpted and added to the laws of hygiene, with the further addition that during such process of oxidation no possibly infective particles shall be given an opportunity of passing from such waste products to the air, water, or food-supplies of the community. Sanitation, founding its rules on the above hygienic law, disposes of all such dead organic matters by the method and in the manner best suited to the actual nature of the substance in question, the richness or poverty of the population concerned, and innumerable other considerations. The methods which it adopts for the disposal of sewage are not the same as those which it makes use of in destroying household refuse, and, again, the means which it employs for the former purpose are different in the various cases of a rich manufacturing town, a small and poor rural district, and a military cantonment in India or South Africa.

To take another instance : In accordance with a universal physical law, hot air rises and cold air descends. Since, as a result of human respiration, air is vitiated in various ways, hygiene adopts the above law, and utilizes it for the removal of used air from, and the supply of fresh air to, the habitations of man. Sanitation, recognizing the law, formulates in accordance therewith its rules for achieving ventilation, with the significant addition that the necessary changes must be made without causing any sensible "draught," realizing that human nature must be kept in mind when the laws of science are adapted to the needs of daily life. And,

again, though the physical law quoted above is equally true in all climates and all latitudes, the actual mechanism of ventilation is not the same in the two cases of, say, a house in the north of Scotland and a barrack-room in Madras.

On occasion the conflict between what hygiene says should be done and what sanitation recognizes as practicable may be so great that we have to neglect the former in order to effect the latter. In civilized communities such situations but seldom occur ; but in military sanitation, which has to work under barbaric surroundings, instances of this conflict are not rare. I may here relate one such instance in which this conflict was brought very obviously to my notice. In the station of Quetta, in the nineties of last century, enteric fever was prevalent every year during the summer and autumn months, the epidemics gradually increasing in severity, until in 1898 they culminated in one of the worst outbreaks—if not the very worst—that ever occurred in India. The European garrison consisted at that time of two battalions of infantry and three batteries of artillery ; one of the infantry battalions had only lately arrived at the station, though it had been some three years or so in India. The remaining units had all been in the station some time. The annual epidemic began rather later than usual, but between the beginning of August and the end of October—when, as usual, it came to an end with the beginning of winter—there were 232 admissions for enteric fever out of a force of Europeans numbering only 213 and of these

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lately arrived in the station, and contained a large amount of susceptible material. The other infantry battalion suffered rather more than the artillery, whose barracks were behind and some little distance from the western end of the infantry lines.

The outbreak was so severe that in the case of the battalion which suffered most, recruiting in the county from which it came was seriously affected. The situation was undoubt-

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The outbreak was so severe that in the case of the battalion which suffered most, recruiting in the county from which it came was seriously affected. The situation was undoubt-

edly most serious, and it became imperative to take some steps to prevent a recurrence of such a state of affairs. It will be remembered that in those days enteric fever was universally looked on as a water-borne disease, and the possibility of any other method of dissemination was hardly considered, and, if suggested, derided. The water-supply of Quetta was exceptionally good, and for reasons to which I shall refer later, when discussing the causation of enteric fever in India, the authorities in the station came to the conclusion that the danger lay in the filth trenches. These were situated to windward of the lines, and though, on account of the arid nature of the soil and the absence of water, which was not procurable, they were not properly worked, I have no reason to doubt but that oxidation of the fæcal matter was proceeding, though slowly. The decision arrived at was to shift the disposal ground to some safer spot, but this was not easy to find. To go to leeward of the lines was impossible for many reasons, one of which was that the water came from mountains in that direction, and we should have been working in proximity to the pipe line and the service reservoirs. There was ground available situated directly north of the lines, along a good road, but unfortunately it was impossible to go more than half a mile along this road without coming into the line of fire from the infantry ranges. However, as there was no other locality, there was nothing else to be done, and this position was chosen, though it was closer to the barracks than the existing trenches. At the same time, it was impossible to carry out any shallow burial of the excreta—the only method which is at all scientific, since in that manner only can oxidation be hoped for—for the reason that this would result in bringing the plague of flies, already sufficiently dangerous, closer than ever to barracks. It was therefore decided to bury the excreta in deep pits, measuring about 30 feet long, by 15 feet deep, and 6 feet broad. It was intended that the filth for each day, after being placed in the pit, should be covered with earth, but as the soil was mainly a very coarse shingly gravel, this sank through the mass of ordure, which was thus brought nearer to the surface. Accordingly, the filth was merely poured into the pits, and allowed to accumulate until within a foot of the top. By

this time a dense scum had formed, owing to the rapid drying of the topmost layers of sewage, and a septic action took place in the subjacent fluid. There was no percolation through the soil; this was proved by digging pits close to those already full, and there cannot possibly have been any oxidation of the mass of putrescent organic matter. Considerable nuisance resulted in the immediate vicinity of the pits, but as the wind had never been known to blow from that direction into barracks, this did not affect the garrison, though it closed for purposes of exercise one of the few roads out of the station. The number of admissions for enteric fever in 1899 was a little over thirty, though a fresh infantry battalion which had come from Rangoon, where enteric fever is rare, to replace a battalion that had been through two epidemics in Quetta, was thus introduced. I am quite aware of the danger of arguing on the lines, "Post hoc, propter hoc," and I admit that no point can possibly be proved in that manner; but, knowing the station as well as I did, I can think of no other cause for the reduction of enteric fever that actually did occur than the extremely unscientific method that we adopted for the disposal of excreta. The original recommendation, for which I was responsible, did not contemplate that this method should be continued longer than would be necessary to institute a more scientific method in a more suitable locality, to which the excreta should be removed by a light railway. As more than a temporary expedient such a method is naturally indefensible, and nothing but the exceptional circumstances of the case justified its adoption, even for a short time.

The sanitary officer must always remember that his duty is to prevent disease, under the conditions under which he actually has to cope with it. To do this, to escape some emergent and pressing danger, it may be necessary for him to violate some law of hygiene, and thereby incur another, perhaps even a greater, danger in the future. Such a step is only justifiable when the man who takes it does so knowingly, and with his eyes open. Acting thus, he will be able to prepare himself to meet, and if possible escape, the future retribution which inevitably visits all infringement of natural laws. Such methods must not be adopted to meet trivial situations; the greatness of the danger must be the measure

of the excuse ; but the man who is not ready to accept the responsibility of breaking, if necessary, all and every hygienic law, so as to cope with a desperate sanitary situation, will find himself in much the same situation as he who subordinates the instinct of self-defence to the obligations imposed by the sixth commandment.

The student of hygiene may be judged by his opinions, and these can be tested by the exactness of their agreement with the laws of natural science and physiology. The sanitary officer, on the other hand, can only be judged by the results of his work. The highest ideals of hygienic sanctity are no excuse for an exaggerated sick-list, though one is sometimes tempted to think that they may occasionally, in the hands of bigots, form—at least in part—its explanation.

Scope of Hygiene and Sanitation.—In the widest sense hygiene and sanitation are concerned with all preventable diseases and under all possible situations, and textbooks dealing with these subjects aim, as a rule, at an equal catholicity. In actual practice the medical officer of health concentrates his attention on those more or less limited aspects of the science and the art which affect directly the population under his care. This is more particularly true of the so-called "trade sanitations," in which the population is limited in numbers, very often in sex, and, of course, always in occupation. This limitation is especially true of military sanitation. Here the population is small, is confined to one sex, and to members of that sex between certain narrow limits of age. A population so homogeneous implies a correspondingly restricted range of disease, and in our army this is more particularly the case, since one particular class of disease to which the population in question is, on account of its age and sex, peculiarly liable—namely, venereal disease—is by national choice and custom excluded from the purview of the sanitarian.

The Military Population.—The military population consists of young male adults, specially selected as being free from organic disease, or, in the popular phrase, "sound in wind and limb" ; living in organized communities in specially built houses ; leading a life of moderate physical exertion, free from all immediate anxiety as to employment

or food ; liable at times, however, to be exposed to vicissitudes of climate to which they have been previously unaccustomed, and also to the exceptional strain, both physical and mental, which is implied by the words " active service." The most striking peculiarity, however, about this population is that its members no longer lead the individual life of the civilian, but, instead, the communal life of the soldier. We shall find accordingly that the problems of sanitation, as they confront us in the case of the soldier serving in the United Kingdom, are concerned almost entirely with this change from the individualistic to the communal life. At the outset of a soldier's career—as, for instance, in his physical training—allowance is made for individual physical peculiarities, but eventually he must learn to do what his comrades do, and in the same manner and at the same time as they. He must live in the same building, eat the same food, march at the same pace, and share the same hardships ; and eventually he must, if necessary, die with them, for the sake of the community to which they all belong. The communal life of the army is, in fact, one of the essential features in that training which is intended to fit the soldier for the performance of that last supreme duty. Its influence is to be traced at every stage of his career, and it modifies all his surroundings. The sanitary officer must therefore never lose sight of this essential fact ; he must remember that his recommendations affect not single individuals or small households, but large aggregates of men. Such recommendations, if accepted, will be carried out with the momentum of a regimental organization behind them, and therefore carried out more perfectly than under any other system. At the same time, this power, like all other massive forces, has the defects of its qualities, and lacks the elasticity which is a characteristic of less ponderous agencies. It is most important, then, that it should not be brought to bear on any problem until the sanitary officer is thoroughly satisfied that the line of action he is recommending is the right one. There must be no chopping and changing of plans ; no raw haste, and no vacillation once the work has begun.

There is one very delicate aspect of the communal life which I must just refer to. The units of which the army is composed have histories going back in some cases for more

than 200 years—histories of which they are justly proud, and which it is the duty of every individual in the unit to know. Linked up with these histories are many small peculiarities and customs, which mean nothing to an outsider, but are full of significance to the members of the unit. It is the duty of the sanitary officer to recognize these, and never on any account needlessly to interfere with such traditions. It rarely happens that there is one way, and only one, of arriving at a desired object; the longest way round is very often the shortest way home, in administration as well as geography.

I have already said that sanitation may be called the art by which man adapts himself to his surroundings, since the diseases at the prevention of which it aims are due to causes existing outside the human body. In the case of military sanitation this is more particularly true, since *ex hypothesi* the population with which it has to deal is at the outset free from all organic disease, "sound in wind and limb." It is worth while, therefore, to devote a short time to considering the nature of these external disease causes.

All theoretically possible causes of disease existing outside the human body may be divided into two classes—namely, (1) those which remain always outside the body; and (2) those which, existing originally outside the body, can, nevertheless, enter into the body, and which, unless they can so enter, are impotent to produce any disease therein.

Amongst the causes which must be included under class (1) are heat, cold, and the other various conditions which together form what we denominate "climate," hunger, thirst, occupation, etc. It is not more than twenty years ago that almost all the diseases from which the soldier suffered outside the British Isles were attributed to one of these causes—namely, climate. The blessed word "Mesopotamia" had never a more consoling effect in theological circles than "climate" for many years possessed in the region of epidemiology. I have seen in some cases the peculiar infectivity possessed by syphilis in certain parts of the world even attributed to this cause. At the present day climate as a cause of disease has lost all the prestige which it once possessed, and, indeed, it may be said that no one of all these theoretically possible causes of disease,

nor even any aggregation of them, can ever cause disease. A man may be hungry, thirsty, ill-clad, and exposed to the extreme of either heat or cold ; he will nevertheless not contract any specific disease thereby, though he may suffer severe injury. Disease, as apart from injury, is attributed at the present day to the second class of external disease causes—namely, those which, existing originally outside the body, can nevertheless enter into it, and produce disease there—in other words, specific pathogenic micro-organisms. But here, again, it is accepted that these alone are not necessarily capable of producing disease, even after effecting an entry. Every man possesses a certain natural power of resisting such an attack, and in military sanitation we have to deal with a population whose powers of resistance are, or theoretically should be, except in respect of one particular disease, at their very highest. We see, then, that, as regards the soldier, disease should be theoretically impossible, unless he is attacked at the same time by some cause belonging to the first class, which, by producing an injury, lowers his powers of resistance, and also by some disease germ which takes advantage of that weakened defence to time its onslaught. Now, the causes which lower a man's powers of resistance to disease are closely connected with the work he does, the quantity and suitability of the food that he eats, the sufficiency and otherwise of the shelter provided, and so on. All these things are far more under the control of the sanitary officer in the army than under that of the medical officer of health, who has to deal with a civilian population. The former has, therefore, a double advantage over the latter, since he starts with a healthy population, and the conditions which militate against the maintenance of that state of health are to a very great extent absolutely under his control.

We may divide sanitation in the army, then, into two main headings—namely, the preservation of health, which deals with all those external disease causes, which, as I have said, remain always outside the body ; and the prevention of disease, which is concerned entirely with the attack made on the individual man by disease germs.

The duties of the medical officer, *qua* hygiene and sanitation, include, then, the maintenance of health and the pre-

vention of disease, and of these the former comes both in time and in logic the first. The Report of the Army Medical Department for 1909 shows that only one man in forty was, on any one day, in hospital throughout the army at home and abroad, and only one man in fifty if the army at home be considered. Again, every medical officer of any experience knows that the sick list is furnished by comparatively few men in any unit; the great majority never see the inside of a hospital. It is on this majority, which I should feel inclined to put at a strength equivalent to 75 per cent. of the whole army, that the eyes of the medical officer should chiefly be fixed.

I have been speaking so far of the prevention of disease only, and of the maintenance of health as a part of that system. But it would be a great mistake to limit the importance of the maintenance of health by confining it to so restricted an area of influence. The soldier is essentially a man of action, and it is the duty of the military medical officer to see not only that he keeps clear of hospital, but also that he possesses in the highest degree all his physical powers. It is in this direction that the medical officer can come most prominently forward as taking a part in the active executive work of the army in war. The study of the physiology of the soldier's life, of the effect produced on his constitution by his work in peace and in war, is even more important than a study of the diseases to which he is most usually exposed. Such study will not only help to keep the man out of hospital, but will also make him, to use an old phrase, a better man of his hands whilst he is in the ranks. This side of a medical officer's activities has not so far, I think, received the attention it deserves. The older army surgeons—Pringle and Jackson, and in later years Parkes—recognized its importance. Since the days of the latter it has fallen somewhat into neglect, but the institution of a special course at the Royal Army Medical College directed entirely to this study indicates a great advance in the policy of the Medical Department in this direction.

As in all other trade sanitations, the work of the sanitary officer in the army is affected by certain conditions and considerations, some of which are common to all trade

sanitations, some peculiar to the trade of the soldier alone. I propose to discuss these in detail.

In the first place come pecuniary considerations. In time of peace pecuniary considerations, questions, that is, of cost, are paramount. To put the matter in the crudest way, the soldier has a certain pecuniary value, of which the State is the responsible owner. Any such value is calculable in terms of pounds, shillings, and pence, and all such values are liable to depreciation, against which the prudent owner attempts to insure himself. The amount of money to be paid in insurance on any valuable article is readily ascertained by trained actuaries. Sanitation is one form of insurance, and the amount of money that should be expended on sanitation is just that amount which, under ordinary conditions, due regard being had to the capital represented, will safeguard the owner of the valuable article against loss or depreciation; in other words, will protect the soldier from physical inefficiency and disease. In private life this point is, of course, readily recognized, and every man regulates his expenditure on the sanitary improvement of his own house by this rule. The mere fact that the sanitary officer has not to deal with his own money, but with that of the nation, should make no difference, or if this fact be permitted to affect his point of view, then it ought only to be in the direction of making him balance even more carefully the pros and cons of his recommendations from the financial aspect. It is true that the position occupied by the Medical Department in the general scheme of military administration does not throw on the sanitary officer the onus of actually deciding whether or no any proposed expenditure should be incurred. His position is merely advisory. His responsibility is, however, in no way lessened by this fact. A sanitary adviser who has no military status or training, may be forgiven if he bases his advice on purely theoretical considerations, since he is not in a position to visualize the situation from any other than the one aspect. The military sanitary officer, however, who aspires to be looked on as an integral part of the army, can allow himself no such latitude. In virtue of his position and experience he is enabled to view all sanitary questions equally from the sanitary and the military side, and his

advice must therefore be based on a consideration of the position under discussion, not only as it affects the health of the soldier, looked at as a human being, but also as it affects his value regarded merely as a national asset. It is true that improved health and increased value go hand in hand ; the former connotes the latter. But the advisability and practicability of the methods by which it is proposed to attain these ends depend largely, in peace time entirely, one may say, on their cost, and must be so estimated. I have known, and I do not imagine my experience is unique, sanitary officers make recommendations which I feel sure they would have thought twice and oftener over if the money had had to come out of their own official budgets. I have known recommendations made of such magnitude that it would have been cheaper in the long-run to move the garrison concerned than carry out the proposals suggested. Such conduct may be magnificent ; it may even be consonant with the most perfect hygiene ; it is most decidedly not sanitation, which, before all, has to adapt itself to its surroundings. To make recommendations which are impossible on account of expense is just as foolish as to suggest measures which run counter to some natural physical law.

There is a particular class of consideration that affects very importantly sanitation as it is practised in the army, for which I will use the term "industrial considerations." These are due to the labour conditions in countries where civilized workmen are not available. In India, for instance, the art of plumbing, on which so much of modern sanitation depends, is unknown. Schemes which, for their completion and upkeep, demand the work of skilled plumbers are, therefore, impracticable. I state this merely as an instance — it is not the only example—of the necessity of recognizing the fact that the rules of sanitation can only be applied through the industrial machinery locally available. The ambitious projects of the young sanitary officer fresh from home, with the ink hardly dry on his hard-won diploma of public health, wilt under the cold eye of the native water-carrier and the low-caste sweeper. Not infrequently in his eyes the senior officer, who realizes the true inwardness of the situation, must seem backward and

effete. This stage of thought is one which we all go through, and in warning young officers of its existence, I do not do so with any vain hope that they will thereby escape the salutary experience. It is, as it were, a disease from which complete immunity can only be purchased by suffering from a severe attack, sometimes from several attacks. It often takes many years and many rebuffs before one realizes that one cannot put the new wine of modern sanitation into the old bottles of native custom and prejudice.

The last series of considerations with which the military sanitary officer has to reckon are military considerations. In time of peace these have little or no weight. Speaking from a fairly wide experience of sanitary administration, both in India and at home, I can say confidently that I have never known any important sanitary project rejected as impracticable on purely military grounds, provided only it were well reasoned in conception and clearly stated in argument. I have known sanitary officers complain of their schemes having been refused in this manner, but I have invariably found that the fault lay on their own side. Either the scheme was badly worked out, or the arguments brought forward in its favour were loose and unconvincing. In time of war, and to a less extent on manœuvres, which are, *ex hypothesi*, the picture of war, military considerations are paramount, and rightly so. In time of peace the soldier is merely learning his trade, and it is necessary that he should be kept in good health for that purpose. On manœuvres, too, he is still merely learning his work, but now with some approach to experiencing the actual rigour of real war. It is reasonable, therefore, that on manœuvres he should be called on to undergo, in some modified way, the exposure and hardship that he will inevitably have to suffer when war comes. In war he is no longer learning his work, but actually performing it, and that work is of such paramount importance to the nation that no considerations whatsoever of life or health must be permitted to interfere with its execution or hinder its success. The duty of the military sanitary officer in time of peace is, like that of all other sanitary officers, to preserve the health of the population committed to his charge. The duty of the military sanitary officer in time of war is, like that of every other individual

in the army in time of war, to defeat the enemy. Since that defeat is the result of certain physical activities on the part of individual soldiers, culminating in the killing of certain individual soldiers on the opposing side, it is obvious that it will be achieved the more surely and rapidly, the higher the level of physical efficiency—that is, health—at which the sanitary officer can maintain the soldiers of the army to which he belongs. Their health is not an end in itself, but only a means, a very important means it is true, but still only a means—to an end, and that end is the defeat of the enemy. But the price of success in war is human life and suffering, and it is for the Commander to decide on the terms of payment. He may decide to pay the price in exhaustion and disease, or in terms of bayonet and gunshot wounds. He will choose, presumably, that method of payment which seems to him the most convenient and the cheapest, but in any case the choice rests with him, and not with the medical authorities.

Two of the chief factors in any strategical problem are time and numbers. The Commander may decide that it is more important to be at a certain spot at a certain date in diminished numbers rather than to be at the same spot two days later in increased strength. A very striking illustration of this point is given by Marlborough's campaign in the Low Countries in 1711. He was on that occasion opposed to Marshal Villars, the Commander of the French Army, and it was necessary for him, if he would avoid a desperate assault on a strongly entrenched position, to seize a certain point by a certain time. If successful in this, it would be unnecessary for him to expose his men to further risk of punishment under the fire of the enemy. Calling on his troops for severe exertions, he attained his object, the right wing of his army covering forty miles in eighteen hours. Long before the position was reached, in the words of Mr. Fortescue : " The severity of the march began to tell heavily on the foot. Hundreds dropped unconscious, and many died there and then, but they were left where they lay, to await the arrival of the rearguard ; for no halt was called, and each regiment pushed on as cheerfully as possible with such men as still survived." As a result, the next day Marshal Villars offered battle under the walls

of Cambrai, but Marlborough had already won the rubber, and declined to reopen the game. The fortified town of Bouchain surrendered under the very eyes of Villars who, outmanœuvred by this desperate march, was unable to interfere, and "with its capture the last, and not the least, of Marlborough's campaigns came victoriously to an end."

Another very striking illustration is to be found in the career of Stonewall Jackson. Colonel Henderson says in his Life of that great General (vol. ii., p. 482): "His victories were won rather by sweat than by blood, by skilful manœuvring rather than sheer hard fighting. Solicitous as he was of the comfort of his men, he had no hesitation, when his opportunity was ripe, of taxing their powers of endurance to the uttermost. But the marches which strewed the wayside with the footsore and the weaklings won his battles. The enemy, surprised and outnumbered, was practically beaten before a shot was fired, and success was attained at a trifling cost." Jackson himself said: "I had rather lose one man in marching than five in fighting." In other words, he knew that victory was cheaper when bought, as it must be in the first case by suffering and disease, than when purchased by wounds and violent death on the field.

The sanitary officer who should object to such a method of purchase, because it conflicted with some textbook rule of hygiene or sanitation, would stand convicted of ignorance of the merest elements of his craft. His duty is to acquiesce, and see to it that the coin in which the price is paid rings true, and is full value. It was the footsore and the weaklings who strewed the wayside of Jackson's marches, and thereby not only increased the cost of his victories, but made those victories less certain. It is for the sanitary officer to see that the footsore and the weaklings are as few in number as possible, and that if a man must die from exhaustion, or disease the result of exhaustion, it should be due to no cause which medical science could have obviated.

I have used Marlborough and Jackson to illustrate my argument, since their worst enemies never accused either of these leaders of being battle shy, and both were conspicuous for their care and solicitude for the comfort of their men. The first named is stated on one occasion to have taken a

footsore private into his carriage, and the latter stood sentry over his weary men on the march to Bull Run sooner than that they should be disturbed. Their plans were not affected either by any aversion to the ordeal by battle or by any indifference to the sufferings of their soldiers. They knew that victory was to be bought only at a price, and they merely chose the currency in which that price should be paid. It is not for the sanitary officer to cavil at the price or the terms of payment; his duty consists in seeing that the currency is not depreciated.

The recommendations of the sanitary officer in time of war must then be carefully drawn so as to fit in with the general scheme of the campaign, and with the basic principles of strategy. To enable him to do this it is his duty in peace-time to study those principles by reading not only the textbooks in which they are laid down, but also military history. It is probably true that no guide to knowledge can ever quite replace actual experience, but for individual experience to be really valuable it must be compared with the experience of others, and thus a true parallax for the solution of any problem obtained. Experience and study of history combined will give a man a stereoscopic vision, in comparison with which that supplied by either alone is weak and narrow. But the experience of the man who has never thought over and analyzed his experience, is often the most dangerous and fallacious of guides. Frederick the Great's famous baggage mule still remained a baggage mule in spite of its numerous campaigns, and many a man has had as much experience as that well-known animal, and still remained like it, intellectually, in the position from which he started.

The reading of the sanitary officer should comprehend not only the systematic treatises, such as Napier's "History of the Peninsular War," or Mr. Oman's later study of the same period, or Mr. Fortescue's magnificent "History of the British Army," but also, and even more importantly, perhaps, memoirs of individual soldiers of all ranks; the humbler the rank, the more valuable the memoir. Sanitary officers frequently find themselves in stations where it is difficult to procure scientific works dealing with their own special subject. The stations where military literature

of the kind I have referred to is not procurable are few indeed. In a fairly extended experience of Indian service I can only remember one such, and in that a circulating library kept up by the Intelligence Department at the headquarter station thirty miles off was available. There is, then, no excuse for medical officers who neglect this side of their education.

In connection with this subject I should like to impress on all students of military sanitation the benefit to be reaped from a study of imaginary problems. I am quite aware that such study is irksome, and many men will probably say, or at least think, that a knowledge of sanitation and of the service combined is quite enough to enable them to meet offhand any problem when it actually does face them in concrete form. They resort, in fact, to the ancient excuse of the amateur actor : " It will be all right on the night." We all know that amateur, and also the dismal failure that usually results " on the night." Most of us know officers whose performance in a crisis has for similar reasons come equally short of their confident promise in advance.

CHAPTER II

SANITARY ORGANIZATION

The chief sanitary authority of the army, in peace or war, is the Director-General of the Army Medical Service, and this authority is exercised by him in the form of advice to the Secretary of State for War and the Army Council through the Adjutant-General. The position of the Director-General, and his relation to the chief military authorities, is duplicated throughout the service by the relationship of Principal and Administrative Medical Officers to Commanders-in-Chief and General Officers Commanding divisions, and again by the relationship borne by medical officers in charge of effective troops to officers commanding individual military units. Every military officer exercising command has at his disposal a medical officer as his responsible sanitary adviser. The medical officer has no executive authority except such as is delegated to him as a staff officer of the commanding officer. The latter is responsible for the due execution of the measures recommended to him by the former, and is also responsible for co-ordinating these measures with the general military situation. It must be obvious that the only person who can really effect this co-ordination is the man on whom the responsibility for the success of the military operations in progress rests, and this is equally true of a subaltern commanding a company and a Field-Marshal commanding the massed forces of the Empire.

But though this is true, and an inevitable consequence of rational military organization, it in no way lessens the responsibility that devolves on the sanitary officer, of seeing that the advice he gives is such as will not conflict obviously with strategical or tactical principles. Any medical officer

of health could give the commander the necessary advice to meet the sanitary situation considered by itself. The military sanitary officer has no *raison d'être* unless he is prepared to envisage the military aspect of the problem as well, and frame his recommendations accordingly. He has no right to throw on the shoulders of a man, already sufficiently burdened with responsibility, the onus of deciding the relative importance of a series of recommendations, concerning a technical department with which he cannot be expected to be thoroughly acquainted.

Lord Wolseley in his " Soldiers' Pocket-Book " says some very crushing things on this subject, and recommends Generals to leave their sanitary officers at the base, stigmatizing the whole matter as " a modern fad." If tradition be true, he had some reason for his wrath. Sanitary officers who will not recognize the true inwardness of military sanitation and its position in the military scheme, are far too near the front if they are at the base of operations. It would be difficult, in fact, to find a suitable situation for them consistently with the retention of their names in the Army List.

Principal and Administrative Medical Officers are assisted in sanitary matters by specially qualified sanitary officers, on whom they rely for the supervision of the details of sanitary administration in the force of which they are in charge, and also, should they feel the need of it, for expert advice. The sanitary officer is a staff officer to the Principal or Administrative Medical Officer, as the case may be, and not to the Commander-in-Chief or the General Officer Commanding. This position is sometimes misunderstood, and therefore a few words as to the absolute necessity for its existence may be pardoned.

The responsible adviser of the General in all matters connected with the sick is the Principal Medical Officer. The number of sick that will need to be provided for must naturally vary with the extent and efficacy of the measures adopted for the prevention of disease. A very simple illustration will suffice. Suppose a force to be operating in an area where the water is known to be bad. The amount of sickness will depend on whether or no sufficient measures are taken for the purification of the water. Clearly, if no

sterilizing apparatus is taken, a greater amount of hospital accommodation will be needed. The Principal Medical Officer could not logically demand the provision of transport for his sterilizers and at the same time for the increased hospital accommodation necessitated by the fact that the water was bad. If his sterilization is not going to lessen the sick-list, the apparatus may as well be left behind. Obviously, if there is a condition of divided responsibility—if one man is responsible for the prevention of disease and another for the care and treatment of the sick, duplication of the kind I have just suggested will inevitably occur. The only possible way of avoiding such duplication and the resulting inevitable friction is to keep the two—prevention of disease and the care of the sick—under the one man. The principal medical officer may, of course, delegate his sanitary powers very largely to his sanitary officer. He cannot delegate his sanitary responsibility, which is inalienable.

The divisional sanitary officer is undoubtedly a very important link in the sanitary chain. Speaking of India, where alone I have any personal experience of the work, I know that he can render the greatest possible assistance to his principal medical officer and also to his other brother officers of his own standing in charge of stations in the division. Within the first three months he should know the general topography of every station in it, the general distribution of barracks, and the class and medical history of the troops occupying them. It is far easier to submit recommendations for a station which one has actually seen than for one known only from plans.

His laboratory work should take a second place. The real workroom of the sanitary officer is the barracks, and unless and until he knows them thoroughly, his advice with regard to them will lack actuality. Ignorance in this direction is the unpardonable sin.

So far I have been speaking of sanitary administration as it concerns the Medical Department, but it is an error to suppose that the matter ends with that branch of the Service. The executive sanitary officers of the British Army are the squadron, company, and battery officers. It is on them and on the extent to which they realize the assistance that sanitation can afford them in the execution of their

military duties that the health of the army ultimately depends. An army that relies on its sanitary officers for its health would be in much the same position as one which relied on its Adjutant-General for its discipline. It is the duty of sanitary officers to try and make regimental officers recognize their responsibilities in this direction, and also to point out to them the very real value that sanitation possesses from the purely business point of view—that it means full ranks and ranks full of healthy men. Just as the executive sanitary officer is the regimental officer, so the actual maintenance of sanitation depends on the rank and file. I do not refer to those men in every unit who are told off for actual sanitary duties, though they play an important rôle, but the individual warrant officers, non-commissioned officers, and privates, from the sergeant-major to the last-joined recruit. Unless these can be got to recognize the value of sanitation—again from the purely business point of view—there will be no sanitation in the unit. There will be plenty of standing orders, no doubt—probably in direct ratio to the amount of disease in the unit—but there will be no real sanitation. This is, of course, to a certain extent a matter of instruction, but much more a matter of example ; and the sanitary officer is not the person who should be responsible for imparting either. I feel very strongly that in a question so closely linked up with the internal discipline of the regiment, battalion, or battery, there should be no intermediary between the regimental officer and his men. If any such is allowed, the men and officers will come to look on sanitation as some extra-regimental affair, worthy, no doubt, of the recognition and acceptance due to all such matters ; they will not recognize it as what it really is—an organic part of the regimental life.

CHAPTER III

THE RECRUIT

THE first consideration of the sanitarian is the physical condition of the population amongst whom he has to work. It must be, therefore, our first task to discuss the conditions under which the soldier enters the ranks before we consider his work and the surroundings in which he has to live.

TERMS OF ENLISTMENT.—The British soldier enlists between the ages of eighteen to twenty-five for two periods of service, which together aggregate twelve years, and which are distinguished as service with the colours and service in the reserve. The relative length of these two periods varies in different arms and also at different times as a result of changes of national policy. The most important classes—viz., the infantry and cavalry of the line enlist for seven years' colour service and five years in the reserve. The sappers of the Royal Engineers enlist (in part) for a similar period. The Royal Horse Artillery enlist for two periods of six years. The Brigade of Guards and the Royal Army Medical Corps for one of three with the colours and of nine years with the reserve.

The period of colour service of the man in a line regiment, though called "short service," is, in fact, long service when we compare our army with any one of the continental armies. This is necessitated by the fact that we have to keep about one-half of the army constantly abroad, and therefore must insure men serving overseas long enough to repay the cost of passage.

Our army is enlisted on a voluntary basis, and it is interesting to note one of the physical effects of this. Since the service is voluntary, and the engagement for a limited period

only, it is too much to expect that men who have already got settled down to a job in civil life will throw up their work for a purely temporary benefit. The men we get are therefore the men not in regular work, very often men who have never been in regular work. According to the Report of the Director-General of the Medical Service for 1909, the proportion that were more or less unemployed on enlistment was about 90 per cent. This being so, and the ranks being open to lads of eighteen, it is obvious that we must enlist a considerable number of immature and underfed lads—a point alluded to in the Report already quoted. This is a natural corollary of the voluntary system of enlistment, and from a national point of view the early age at which we take recruits possesses a very distinct advantage. It is far better to take a lad who, morally, is more pliable, and who, physically, has not suffered much from unemployment, than to wait till a later period, when both mind and body have deteriorated as the result of an extra year or so of "loafing." These facts, however, of immaturity and physical poverty must be kept in mind when the effect of the training and work of the young soldier are being considered. This point, also, is referred to by the Director-General in his Report for 1909, as follows: "It should not be forgotten that many of the lads will be incapable of doing the work of a seasoned soldier for at least two or three years." Similar notes have been made in previous Reports, and, indeed, nothing else is to be expected. A lad cannot at eighteen do the work of a man, and we have to pay for the fact that we get the recruit at an age of greater moral and physical receptivity by the comparative disadvantage of having to keep him more back in his training than we would otherwise do.

In other countries with universal service the age of liability to service varies from seventeen to twenty-one, but the majority do not take their men till at least twenty. This is in part due to the fact that their service is so much shorter than that in our army. It would be impossible to recruit line regiments for two or three years—the usual continental period—if men entered at eighteen. As one result our soldier of twenty years of age has two years of training and of good feeding to his credit, as compared

with the continental recruit of the same age, and the nation retains his services for five years longer with the colours. More than half our men come to us under twenty, and the result is that we possess a class of soldiers of from under twenty-three to twenty-seven with more training and physically better "set" than are available in any other army.

Physical Standards—*Height.*—The height of the British recruit averaged in 1909, 5 feet 6½ inches. This was ½ inch higher than the average for the previous decade. The actual minimum standard varies somewhat with labour conditions, but is fixed at present at a minimum of 5 feet 4 inches for infantry of the line, and 5 feet 4 inches to 5 feet 6 inches for cavalry. Departmental corps allow of a somewhat lower standard, whilst the Royal Horse Artillery fix 5 feet 7 inches for all classes (except artificers); the Royal Field Artillery 5 feet 7 inches for gunners, and 5 feet 5 inches for drivers; the Royal Garrison Artillery 5 feet 8 inches for all classes except artificers. Certain *corps d'élite* are able to demand special standards. Thus, the Grenadier, Coldstream, and Scots Guards insist on 5 feet 9 inches, and the Cavalry of the Household Brigade on 5 feet 11 inches. In mounted corps an upper limit is also fixed: 5 feet 8 inches in the line cavalry, 5 feet 7 inches in the drivers of the Royal Horse and Royal Field Artillery, and 6 feet 1 inch in the Household Cavalry.

Increased height does not in these days possess the value that it had in the wars of the pre-breechloading era. Tall men had, in the days of close formations, a distinct moral value when it was a question of close quarters and shock tactics. The comparatively small man, on the other hand, is quicker, as a rule more active, gets more value out of his ration, and does not knock himself about to the same extent as the bigger men on rough ground. ["Les petits resistent long-tems, les colosses succombent de bonne heure. La campagne de Moscou est décisive à cet égard" (Coche)]. The minimum height in Germany is 5 feet 1½ inches; Russia, Italy, and Austria, 5 feet 1 inch. The French fix no lower limit for infantry. The Swedes and Norwegians come up to about our figures. Height is essentially a matter of race and breed. Above a certain limit, which varies with each strain of blood, men are apt

to get weedy, and it is, strictly speaking, unscientific therefore to fix an absolute standard for men so widely different in race as the Scandinavian of the Border Counties and the Celt of Wales, or some parts of the West of Ireland and Scotland. Where the divergencies are greater, as in the case of the Indian Army, this fact has to be taken into account. It would be absurd to have one ruling standard for the Gúrkha, the Tamil, the Mahratta, the Sikh, and the Pathan.

Chest Measurement.—The minimum expanded chest measurement in the infantry of the line is at present 33½ inches for a lad of eighteen under 5 feet 5 inches in height. At the same height, but twenty years of age, 34 inches are demanded. In cavalry of the line the minimum is increased by 1 inch at each of the above ages. Artillery and special corps fix special figures, which need not be detailed. The important point in connection with chest girth is not the absolute tape measurement, but the range of mobility. This is fixed at a minimum of 2 inches, or 2½ inches in the case of men who are exceptionally tall for their age. As regards the absolute chest measurement, this should always be taken in connection with the height. For medium men the chest girth should be rather over half the height, for smaller men proportionately greater, and for taller men proportionately less. It must constantly be kept in mind that the chest girth is one of the most uncertain measurements that can be made. Differences in method—as, for instance, in the height at which the tape is placed in different countries, personal differences in the matter of a taut or a slack tape in the technique of different observers, and varying muscularity of the pectoral region in various recruits—all affect this question materially. Our own standards are fairly in accordance with the rough rule laid down above.

Weight is taken into consideration with age and height. The minimum for infantry of the line is 112 pounds for a lad under 5 feet 6 inches, and eighteen years of age. At the same height, but over twenty, 3 pounds extra are demanded. The cavalry ask the same amount—viz., 115 pounds for both the above classes of men. They also lay down a maximum of 147 pounds for men under twenty, and of 154 pounds above that age. Weight

is a very useful guide to the physique of a man, but must be used with caution. There is, of course, no difficulty in ascertaining the actual weight within the limits of instrumental error, but it must be remembered that weight varies very considerably, not only from day to day, but also from hour to hour, according to the amount of solid and liquid food ingested and the solid and liquid discharges. It naturally should bear a definite relationship to height, and the standard sometimes laid down, which affords a useful rough rule for guidance, is that the weight in kilogrammes should be equal to the number of centimetres of height in excess of 100. Thus, for a lad of 5 feet 4 inches (160 centimetres) the average weight should be 60 kilogrammes, or 132 pounds. For immature lads this is undoubtedly too high a standard, especially if they are not too well fed. Weight must naturally also be taken into consideration with appearance, and obesity excluded.

The average age, height, chest measurement, and weight of the recruit in 1909 were as follows: Age, 19·8 years; height, 66·5 inches; chest measurement (minimum), 33·6 inches, with an average expansion of 2·6 inches; weight, 130·1 pounds. We see that the chest measurement is greater than half the height, and the weight in kilogrammes 7 less than the odd centimetres of height over 100. This points to a man rather under the average in height (which is to be expected at the age), well proportioned, but rather wanting in muscular development. These standards may be compared in another way. A French army medical officer, Pignet, has devised a formula which goes by his name, in which the weight in kilogrammes, plus the chest measurement in centimetres, is subtracted from the height in centimetres. The resulting figure provides a numerical index of physical efficiency, the height of the index being in inverse ratio to the degree of efficiency. Pignet classifies his indices as follows: Under 10, "very strong"; between 10 and 15, "strong"; 15 to 20, "good"; 20 to 25, "fair"; 25 to 30, "weak"; 30 to 35, "very weak"; above 35, "useless."

The average height, weight, and chest measurement of the recruit of 1909 give us the following formula: Height (166·25), minus chest measurement (84), plus weight (59·1),

equals an index of 21·15—just a little too high to be "good," but certainly to be classed as "very fair." The figures for the previous decade are a little lower all round—viz., height, 66 inches (165 centimetres); chest measurement, 33·4 inches (83·5 centimetres); and weight, 128·1 pounds (58·2 kilogrammes), giving an index figure of 23·3.

A consideration of these figures shows that the remarks of the Director-General quoted earlier in this chapter are well supported on scientific grounds.

Apart from actual standards of measurement, recruits have to possess a certain standard of health, or, rather, must be free from certain actual ailments or defects. These defects and the method of ascertaining them are laid down in the instructions for medical officers examining recruits in the Army Medical Regulations, and it is unnecessary to detail them here. A few words may, however, be said about the actual cause of rejection.

Out of a total number of 50,298 inspected during 1909, 15,041 were rejected, or 29·9 per cent. Of these 5·8 per cent. were rejected for deficient chest measurement, 1·1 for deficient height, and 0·46 for deficient weight, or a total of 7·4 per cent., for being under standards. Defective teeth accounted for about one-sixth of the total number of rejections; heart disease for one-ninth; defects of the lower extremities, including flat-foot, for one-thirteenth; defective vision for one-sixteenth; varicocele for one-twentieth; and varicose veins for one-twenty-fifth.

The importance of defective teeth is obvious. The ratio of rejections for this cause during 1909 was higher than in the two years immediately previous, but lower than in the years before 1907. The personal equation of the recruiting officer comes very strongly into play here. The condition of the teeth, it should be remembered, is only of importance as affecting the general nutrition. A man with a doubtfully sufficient number of teeth in his head, who is, nevertheless, well nourished, is clearly not suffering from the deficiency in his dental apparatus. The two factors, nutrition and number of teeth, should always be taken into consideration together.

Heart disease plays, as will be seen, an important part. It is occasionally said that the standard laid down by the

military medical officer is too strict in this respect, and that men are rejected on account of functional cardiac disorder in whom there is no organic disease, or at least complete compensation. This is probably true, at least as regards the second part of the indictment. I cannot agree with the first part—namely, that the line is too strictly drawn. The conditions under which a medical officer examines a recruit are very different from those that obtain in a civilian consulting-room. The time for examination is limited, since probably a considerable number of men have to be examined in a comparatively short period. Above all, it is impossible to tell the man to go away, and come back in a few days and say how he feels. The decision has to be made at once. It must be remembered, too, that the army is recruited up to a fixed strength. Any doubtful man taken in, means another possibly better man kept out some weeks later owing to the list for that corps, or arm, being closed. Lastly, it is not sound policy to take such a risk on behalf of the State. There is no use in teaching a man the trade of soldiering if there is even a small probability of his not being able to parade with his unit for service. This is, of course, speaking of recruiting only. Once a man has learnt his trade, and can be kept under observation, then it is reasonable to keep him in the ranks, with a cardiac deficiency or apparent deficiency, which would certainly have kept him out as a recruit.

All recruits can be discharged as unfit within three months after enlistment on the advice of a medical officer. The causes for discharge under these circumstances are much the same as those for rejection of recruits. The total number so discharged during 1909 was 526, or 1 per cent. of those actually appearing for examination. The proportion to the number actually enlisted thus discharged after trial was small, only 1·1 per cent. Loss or decay of teeth was the most important cause. Heart disease and defective vision came next in the list. The total number was less than that for the previous decade, but the same causes were operative in both periods, and in much the same relative proportions. It is interesting to note that this probationary period of three months is a revival of the old Roman custom of probation for recruits.

Social Position of Recruits.—Voluntary enlistment naturally attracts unskilled, or only partially skilled, more than highly skilled labour. Bad times in any one trade will obviously drive more men from that particular employment into the ranks, and the first to go will probably be those who, having just begun to learn their work, have not had time to get settled, or are the first to be turned off on reduction of establishment. Out of a total of 45,000 men examined during the year, October 1, 1909, to September 30, 1910, 20,000 were classed as unskilled, and 10,000 as skilled. Eleven thousand belonged to "occupations classed separately," such as carmen and carters, general porters, domestic servants, tradesmen's assistants, and clerks." This class cannot be considered, except with regard perhaps to domestic servants and clerks, as being skilled in the same sense as shoemakers and factory workers generally. The remaining numbers are made up by professional classes (400) and boys under seventeen (2,000). (Round figures only are given.)

Of unskilled labour 11,000 men are shown as general casuals, 9,500 of these being "general casuals, town." Outdoor unskilled labour gave 7,700 men, mostly agricultural labourers, and indoor unskilled labour, 2,000.

The ratio of rejection was 30.46 per cent., taking all candidates into consideration. Unskilled labour and occupations classed separately gave a higher ratio of rejection than the average, though the difference is not great. General casuals (town) and indoor unskilled labour gave high ratios, the former especially. In general it may be said, with regard to unskilled labour, that the country is better than the town, and the outdoor worker very distinctly better than the indoor. Thus, of agricultural labourers, only 25 per cent. were rejected, whilst general casuals (town) gave 35 per cent.

As regards skilled labour, the rejections were about the average figure for all classes.

The social position of the recruit varies naturally with that of the labour market. Any lad who sees a good opening and prospect of steady employment in civil life is extremely unlikely to risk his chances of ultimate success by enlisting for seven years' service, nor does it appear desirable in the general interests of the nation that he should

do so. On the other hand, the lad who sees no such opening, and who belongs, by reason of the improvidence of his parents, or for other cause beyond his control, to the general casual class, is benefited by the chance of tiding over a certain period in regular employment, with good food and other advantages, without tying himself down for an unlimited period of years, as used to be the case in the "good old days of eighteen hundred and fighting-time." It is interesting to read the remarks of men of that period on the recruit of those days.

Dr. Marshall, Deputy-Inspector-General of Army Hospitals, in a most useful and interesting treatise, "On the Enlisting, Discharging, and Pensioning of Soldiers," written in 1839, says: "The condition of a soldier is very little calculated to induce an industrious man who can obtain subsistence in any other way to embrace it; consequently those who enter the service are commonly thoughtless youths, petty delinquents, men of indolent habits, persons who are unable to procure work, or who are in very indigent circumstances"; and again: "Necessity and not an ardent liking for the profession compels many to enlist, they having lost their character, or contracted habits of idleness or improvidence, which more or less exclude them from the better paid walks of civil industry, by which means they are constrained to devote themselves to a military life." Jackson, many years before, said much the same.

It would be wrong to leave this part of the subject without saying a few words as to the relationship which the recruit of the present day bears physically to his predecessor in the past. The opinions held on this point are often extremely erroneous, and it is important that the young medical officer should have sound ideas on the subject. The *laus temporis acti* is engrained in human nature, and just as a boy leaving school believes that the children just joining can never possibly emulate the feats of the heroes he remembers when he was in their position, so the older generation of soldiers cannot realize that the recruit of the present day is not degenerate when compared with the men he remembers seeing in the ranks when he himself first got his commission. It is permissible to insert here a quotation from the life of a distinguished General, Sir William Butler, which puts the

above belief in better words than I can command. He is writing not long after the Crimean War, and the passage runs as follows :

"Already the result is visible ; the standard has to be reduced ; men are now taken who would have been rejected with scorn a few years ago ; we get recruits no longer from the rural districts, but from the slums of the cities, and even from these sources we find it difficult to obtain them in sufficient numbers. . . . I shall never forget the sorry contrast that presented itself on the bank of the Sittang River at Tonghoo, where one draft of a hundred and twenty men of the new model formed up on the high shore from the boats. The old soldiers had come down from the big teak huts a couple of hundred yards away to see the new arrivals. The contrast between the two sets of men was not flattering to the newcomers. . . . I often look now as soldiers pass, and marvel what has become of these old Greek gods, for not only are the figures gone, but the faces have also vanished . . . those clean-cut foreheads, the straight or aquiline noses, the keen steady eyes, the resolute lower jaws and shapely turned chins. What subtle change has come over the race ?"

It will probably be accepted that the physical condition of the British soldier was never better than in the thirties of last century, when the low establishment kept up and the length of the soldier's engagement made the demand for recruits lower than it has ever been since the Crimean War. In the excellent little handbook already quoted, "On the Enlisting, Discharging, and Pensioning of Soldiers," tables are given showing the average circumference of the chests of the recruits examined in the London District from October 13, 1838 to January 12, 1839 inclusive, arranged according to the height of the recruits. As regards height, out of 609 town recruits passed during this period, 459 were between 5 feet 5 inches and 5 feet 8 inches, 332 being below 5 feet 7 inches. As regards country recruits, out of a total of 391, 310 were between 5 feet 5 inches and 5 feet 8 inches, 217 being below 5 feet 7 inches. Taking both classes together out of 1,000 recruits, 769 were between 5 feet 5 inches and 5 feet 8 inches, 549 being below 5 feet 7 inches. It is probable, therefore, that the average height was, if anything, rather below than above 5 feet 6·5 inches, which was the

average for 1909. As regards chest measurement, the average for men between 5 feet 5 inches and 5 feet 8 inches ranged from 32·54 to 32·53 inches for town recruits, and from 32·66 to 33·13 inches in the case of country lads. The only chest measurement recorded as better than the average for 1909 is 35 inches in the case of country recruits above 5 feet 11 inches, of which there were only two altogether. Weights are not given. The above figures are, of course, small, but since London was the largest recruiting depot at the time, they probably give a fair picture of the average class of recruit taken into the ranks in those days. They certainly afford no grounds for argument as to physical degeneration in the present day. Nor does it appear that a great preponderance of the men were drawn from the country as compared with the town. Judging from some tables given by Dr. Marshall, the numbers actually passed at the Dublin depot between 1826 and 1837 were drawn equally from both classes. This is a less debatable point, however, since the exodus from country to town which marked the latter half of the nineteenth century is above question.

I think that it is of great importance for the young medical officer to recognize that the material with which he has to deal is not markedly different from that which passed through the hands of his predecessors eighty years ago. The recruits I have just been referring to were the men who fought under Napier and Gough in Scinde and against the Sikhs, and whatever their physique may have been on joining, there can be no doubt as to their performances in the field at a later date.

It may be justifiable to apply to this matter the well-known remark in regard to a famous periodical: "The British soldier is not as good as he used to be, and he never was."

The examination of recruits is one of the most responsible duties that a medical officer can be called to perform. Neglect in this respect can more easily cause inefficiency than ignorance of medicine, or lack of surgical skill. It is the more important to recognize this since the actual routine of inspection of the recruit is monotonous and uninteresting. Every young medical officer should remember the motto of Vegetius in this connection: "Nec leve hoc officium putetur, nec quibuscunque mandandum."

CHAPTER IV

PHYSICAL TRAINING

THE expression " physical training " can be, and is habitually, used to express two totally different forms of activity. In the first place, it is used to denote a system of physical education, and in the second to signify the constant practice of regular muscular exercises, with a view to maintaining a condition of muscular " fitness." The confusion is unfortunate, since the two forms of physical training are distinct, not only in their aims, but also in the nature of the exercises demanded by each. In this chapter I will use the words " physical education " to denote the first form, retaining " physical training " for the second only.

Physical education is, like all other education, only a means to an end, and not an end in itself. Gymnastic instructors, like all other teachers, are often apt to forget this, and to think, or rather assume—for the slightest thought on the subject would convince the most obstinate of his error—that the exercises in the gymnasium possess some peculiar virtue of their own, quite apart from their purely educational value.

The first step, then, in considering physical education is to decide the object for which the man is educated. In the case of the soldier this is simple enough. The object of the soldier's education is to enable him to utilize to the utmost all his bodily powers, to the end that he may, with the least physical expenditure, be able to kill his enemy. To enable him to do this he must have complete control over all his muscles of progression, a very high degree of co-ordination of hand, and foot, and eye, so that, even under the stress of intense nervous excitement, his brain shall be in a condition to take in the orders of his officer, and his

muscles execute immediately those orders as they are transmitted from his brain. For the purposes above mentioned great muscular strength is not required, and therefore exercises which have this as their main object are uncalled for. The qualities chiefly required are agility, an amount of muscular development rather above the average, but of a general and not of a localized nature, together with a knowledge of how to " get over the ground " and surmount obstacles in the most economical and rapid manner, either with or without assistance. To put the matter in a rather brutal but very practical manner, the soldier has to be taught those exercises which will enable him eventually to get into a position of advantage from which he can bring his skill at arms to play on the persons of his enemies, with the greatest economy of exertion possible.

The object of his physical training should be to keep him constantly in such a condition of bodily fitness that he shall be able to execute the movements demanded, the most economical method of doing so having been once taught, with the least possible derangement of his circulatory, respiratory, and thermogenetic machinery, and continue doing so for the longest period necessary with the minimum amount of nervous and muscular fatigue.

To return to the educational side of the subject. Physical education, like all education, is general and special. The general education is that which is taught at the outset to the beginner—that is, the recruit. Once taught, it need not be regularly repeated, though occasionally the memory may require to be refreshed. Special education is the professional superstructure raised on the foundation of general education. Here the elements may be taught once for all, and need not be repeated ; but anything beyond this needs constant instruction, and in one sense this branch of education never ceases. As regards the physical education of the soldier, the general instruction consists in the simpler movements of the gymnastic system, or of drill. The special education includes marching with or without heavy loads, running, jumping, climbing, and the negotiation of obstacles of all kinds, at first without, but later wearing, the full equipment of that arm of the Service to which he belongs. The use of the bayonet and rifle, the sabre or lance, are the

finishing steps in this special education, and, as every soldier knows, this part of the teaching never comes to an end, since there is always something more that a man can learn.

The preliminary physical education should occupy the first weeks of the recruit's military life. During this time he will have to undergo vaccination, and in consideration of this, and also of the fact that the lad is often underfed and invariably immature, it is necessary for the medical officer to see that no strain of any kind is inflicted. The movements at this stage should be such only as do not demand the overcoming of resistance. On this account I should omit from the earlier part of the course all span bending, heaving, abdominal, or dorsal exercises. Leg, neck, and arm exercises are all suitable, and some of the lateral exercises. Balance exercises on the beam, raised very slightly or not at all, are excellent as teaching co-ordination. Great use should be made in this period of games, such as skipping, jumping over a weighted string swung round in a circle, and of short slow runs across country. At this stage the greatest possible amount of individual attention is demanded, and each man must be watched as closely as if he were one of a string of horses under training. I feel confident that a great deal of harm is done by pushing the training of young soldiers before they have had time to get the benefit of the plentiful barrack fare. Consideration must be given at the same time to the source of the recruit and his previous occupation, if any. The town "casual" will, as a rule, be fairly brisk and alert, but under-developed; the country yokel clumsy and heavy, but more muscular. In the latter case much more attention must be paid to exercises at games which produce co-ordination. In the former those which encourage muscular development will obviously occupy more time. The town boy is, I think, more apt to give way under the strain of early training than the country lad, and should be carefully watched. I know of no better way of keeping touch with a man's progress in this respect than that of counting his pulse before and after a measured amount of exertion, and noting the rapidity with which it returns to the normal. If the return grows more rapid as the training progresses, the man is improving.

Unless it does, there is something wrong somewhere. The ordinary standard measurements should also be repeated at regular intervals. A recruit should increase in height slightly, as a result of natural growth as well as improved carriage, and should also increase distinctly in weight and chest measurement. Measurements of the leg, arm, and abdomen may also be usefully made, if care be exercised to secure uniformity of method. With regard to the last-named measurement, it is useful to note that it is best carried out with the subject lying on his back. In addition to measurements, however, the medical officer should study the general bodily aspect and activity of the recruit, and note what, or if any, degree of improvement is manifested.

By the end of the sixth week of training it should be possible to begin exercises involving moderate strain. I am aware that this seems rather a timid suggestion, but I cannot see what useful object is attained by going too fast in this matter. A few days too late can do no harm, whilst a premature change may have most serious effects. With regard to exercises involving strain, there is one very simple rule which, to my mind, settles absolutely the suitability or otherwise of any particular exercise. No exercise involving strain should be taught unless that particular form of movement is one which in the ordinary course of his fighting a soldier may be called on to perform. All acrobatic tricks are absolutely ruled out. On the other hand, any exercise involving strain, no matter how severe the strain may be, is justifiable if it is at all probable that the soldier may be called on to perform such a movement in the performance of his duty. Several exercises, such as climbing on to the shelf, or the heaving exercises on the beam and rope entail severe strain ; but since a soldier may be called on to execute these movements in war, he must be taught how to do them in time of peace. On the other hand, span-bending, fall-hanging, and arch-hanging, are movements which under no conceivable situation is a man likely to be asked to perform, and they cause a considerable amount of strain. They are contortionist work, and, therefore, since they cause strain, unsuitable.

In this matter of strain I think we might go even farther than we do, and make the soldier climb on the shelf, or on

the rope or beam, and surmount obstacles, in full marching order. The Swedish, Austrian, and French manuals insist more fully than ours on these points.

Certain exercises are defended on the grounds that, though not directly useful, they enable a man to execute some other movement which is useful, and which he may be called upon at some time or another to perform. I have heard an instructor, for instance, defend one of the dorsal exercises on the ground that it strengthened the muscles which the man would need for digging. This is a very common form of heresy, and permits of no defence. If it is necessary to teach a man how to do any particular thing, as in this case to use a spade, the quickest and most efficient method of instruction is to make him actually use a spade, and correct him where he works clumsily or uneconomically. There is sound physiological ground for this line of argument. Whenever a man learns a new exercise, he has to establish a definite system of nervous intercommunication controlling the action of the active and antagonistic muscles concerned in that exercise. This system of intercommunication can never be so completely established as by actually performing and constantly practising the movement in question. In this connection there is no valid reason for treating a man differently from any other animal. A horse is trained to jump by being made to jump, and, progressively, to jump more and more formidable obstacles ; and in the same way the soldier should be trained to exercise the numerous activities, on the proper and efficient performance of which the success of the army may at some time depend, by the actual exercise of those activities.

In this connection there is one class of exercises now banished from the official manual, the so-called " breathing exercises," which must be referred to. The object of these exercises is, apparently, twofold. They are intended to teach a man how to breathe—an operation, it may be observed in passing, that he has presumably been performing efficiently at an average rate of fifteen times to the minute from the moment he first severed his connection with the maternal placenta—and also to expand his chest. In the French " Règlement d'Education Physique " (1910), in which they are still retained, it is said that their object is

to augment the respiratory capacity by rendering the thoracic cage more supple, and thus improving the oxygenation of the blood. It is directed that they shall be performed on every occasion on which it is found necessary to restore calm to the system, especially after running, jumping, or games. The recruit is told to stand at attention and take a deep breath, keeping the mouth shut as as far as possible.

In the model course of physical exercises drawn up by an inter-departmental Committee in 1904, the importance of these exercises is somewhat insisted on, and reference is made to "those exercises, primarily of the upper limbs, which tend to develop chest capacity, or to exercise the muscles involved in the process of respiration." Later, it stated that they "aid in the elimination of the carbonic acid accumulated by the repeated contractions of the muscles during the lesson." These theories seem to me to be founded on a mistaken theory of the physiology of respiration. An increase in the carbonic acid in the alveolar air beyond a certain limit will inevitably cause increased respiration, whatever the subject may do or try to do. A marked reduction of that gas in the alveolar air will result in apnœa, no matter what the subject may do, or try to do. It is possible by forced and repeated inspiration to cause this last condition, simply as a result of washing out about half the carbonic acid in the air of the alveoli, and the condition is one which, if pushed beyond certain limits, may have serious consequences. The only scientific breathing exercises are those which cause a slight increase in the carbonic acid in the alveolar air, and thus convey the normal stimulus to the respiratory centre which produces increased depth or rapidity of respiration. If the gas accumulates to any extent, as assumed in the Committee's Report, the subject will automatically breathe deeply to get rid of it. No exercise will be necessary any more than any exercise is necessary to teach a man how to drink water when he is thirsty. Air hunger is the most imperative of all appetites, and insists on being satisfied : nothing short of complete mechanical obstruction to the passage of air will prevent its satisfaction. The defence usually brought forward in support of these deep-breathing exercises is that the majority

of young people are lazy breathers, and do not use their lungs as completely as they should. Even assuming the premises, the fact that a lad is a lazy breather is due to the fact that he has not been in the habit of accumulating enough carbonic acid in his lungs to give his respiratory centre the necessary stimulus required to produce increased activity, and until that stimulus is given, he will continue to be a lazy breather. In the same way, a horse out at grass is a lazy breather, and to fit him for the hunting season it is necessary to get him out of that habit. This is done very simply by graduated work, not by any round-about system of gymnastics, and what is good for the horse is equally good for the young human adult. The best breathing exercise for the recruit is graduated running, carefully watched, and calculated to produce a degree of dyspnœa far short of distress. This will provide the normal stimulus to increased respiration, and the less the recruit thinks about how he is going to breathe, the more likely he is to breathe physiologically. The respiratory musculature is quite as capable of managing its own affairs in this respect as is the cardiac.

The general physical education of the recruit should naturally form the bulk of the earlier part of his work in the gymnasium, but it is not necessary to defer his special education till the general is completed. The intercalation of obstacle work and marching, with cross-country running, will help to break the monotony of the course. Once learnt, it should not be necessary for this general education to be repeated, except in the case of particularly clumsy men, or men who have been long in hospital. In this last case the object would need to be, not so much education as graduated exercise, to bring the man into condition.

Position of Attention.—This position, the teaching of which is one of the first steps in general physical education, has an important aspect from the point of view of the medical officer, since it is certain that considerable damage was inflicted on some men by the old position, which entailed an attitude of forced inspiration, and therefore a danger of strain on the heart and large intrathoracic vessels. The position of attention, as described in the " Training Manual " for 1905, was one of continued strain ; the exact squareness

of the shoulders to the front was insisted on, the hips were drawn back, and the chest advanced. It is true that the words "without constraint" were added, but the position was essentially one of constraint, as being unnatural. The knees were well braced back, which entailed contraction of the quadriceps extensor muscle, which is not necessary in the erect posture, and the weight of the body was thrown on the forepart of the feet, necessitating a position of unstable equilibrium. The defects of this position were brought to notice by Surgeon-Major Davy in 1876. The present position ("Manual of Physical Training," 1908, p. 26) is a rational position of attention—one, that is, in which attention can be paid to an order, and the same executed without any delay. Any stiff attitude means that the soldier has to undo, as it were, some work he was doing before beginning to execute any fresh order, and is therefore *ipso facto* not a position of "attention."

A few words may be said about the anatomy and physiology of the erect posture, since these are closely connected with the maintenance of the position of attention over any prolonged period.

The first point to note is that the human body is symmetrically disposed on either side of the sagittal plane, but asymmetrical as regards the coronal plane. From this it follows that it possesses greater lateral than antero-posterior stability when in the erect posture. The second point is that the body is composed from above downwards of several segments which are not rigidly fixed to each other.

The third point is that each of these segments possesses a centre of gravity peculiar to itself, which comes into relation to the point of bearing between that segment and the segment immediately below, and also into relation with the area of support of the body on the ground—that is, the space between the outer margins of the feet.

To maintain an erect posture with the minimum of constraint, it is necessary that the centre of gravity of each segment should be as nearly as possible vertically above its point of bearing, and also as nearly as possible vertically above the centres of gravity and points of bearing of the segments below. The maximum of stability and the minimum of constraint would be obtained if the various

centres of gravity and the various points of bearing were all in the same vertical line, and if that line fell immediately in the centre of the area of support.

The body may be considered as consisting of five rigid segments, which are given in the table below, the point of bearing of each on the segment immediately below being placed opposite.

The head bears on atlanto occipital joint.
,, trunk ,, hip-joint.
,, thigh ,, knee-joint.
,, leg ,, ankle-joint.
,, foot ,, ground.

The most important point of bearing is the hip-joint, since here the weight comes into relation with the supports, and it will be convenient to take a coronal plane running through both hip-joints as a base to define the relative positions of the various centres of gravity and points of bearing. The following table shows this relationship, + standing for in front, − for behind, this plane :

Centres of Gravity.		Points of Bearing.	
Head	−1·0 c.m.	Atlanto-occipital joint	−1·5 c.m.
Trunk	−0·6 c.m.	Hip-joint	±
Thigh	−0·4 c.m.	Knee-joint	−1·0 c.m.
Leg	−2·7 c.m.	Ankle-joint	−5·0 c.m.

Beginning from above, we see that the centre of the gravity of the head is slightly in front of the atlanto-occipital joint. The head would, therefore, naturally tend to fall forward, if not maintained in the erect posture by contraction of the muscles of the neck. The mechanism is that of a lever of the first order, and since the arm of the lever on which the resistance works is very short, but little force is necessary to maintain the position—little more, in fact, than the tonic contraction of the muscles concerned.

The head being fixed on the trunk, the next point of bearing that comes into consideration is the hip-joint. It will be seen from the table above that the centre of gravity of the trunk is behind the coronal base plane, the centre of gravity of the head, and the point of bearing of the head on the spine being also behind that plane. It is obvious, therefore, that at the hip-joint we have the entire weight of the body behind its main support. The resulting

tendency to fall backwards is here counteracted by the powerful psoas and iliacus muscles, assisted to a certain extent by those of the abdominal wall. Here, again, the leverage to be counteracted is small in comparison to the muscular power available. Coming now to the thigh, we find that the centre of gravity is behind the coronal plane, but in front of the point of bearing at the knee-joint. The tendency here, therefore, is to fall forwards, and this is prevented by the tension of the crucial ligaments. It is important to note that in the normal comfortable erect posture the quadriceps extensor of the thigh is relaxed, and the patella freely movable. Below the knee the point of support shifts even farther back, the ankle-joint being 5 centimetres behind the coronal hip-plane. This distance gives the greatest divergence from this plane yet noted, and therefore it is at the ankle-joint that the greatest strain occurs. Equilibrium is here maintained by the active contraction of the soleus muscle, which, as Richer shows, is the muscle which plays far the most important part in the maintenance of the erect posture. Above this point the variations in front and behind of the different points of bearing and the different centres of gravity are so slight that the muscular work necessary to maintain equilibrium is but little in excess of a purely tonic contraction. At the ankle-joint the divergence is so marked that the soleus muscle has to contract actively to keep the body from falling forwards. The work to be done consists in maintaining the centre of gravity of the entire body immediately over the centre of the area of support. This centre lies on a line joining the heads of the two fifth metatarsal bones, and midway between these points. In the old position of attention the weight was thrown on the front part of the foot, thus increasing the work demanded of the soleus muscle. In both the French and the German positions of attention this same fault seems to be committed. During the time that a man occupies the position of attention he is constantly swaying backwards and forwards, the movement of the vertex being about 1·75 inches in the sagittal and about 0·75 in the coronal plane, in the first five minutes. After prolonged standing in this position the movements become much exaggerated. The addition of a load causes a more marked oscillation,

which increases in amplitude with any increase in the load. The position of attention is one of greater stability laterally than antero-posteriorly, on account of the fact that the body is symmetrically constructed on the right and left of the sagittal plane. This stability can be increased by increasing the area of support, by separating the feet laterally, as is done in the "stand-at-ease" posture. Here, too, the antero-posterior stability is increased by the fact that the hands are lightly clasped behind the buttocks, thus affording a certain counterpoise to the weight of the trunk. In head-tracings taken in this position, it is found that the weight of the body is systematically transferred from one foot to the other. This position is undoubtedly an improvement on the old lop-sided "stand at ease," in which all the weight was brought on to one leg, whilst the other played a purely passive part.

It should be kept constantly in mind that all positions except the recumbent are positions of unstable equilibrium, demanding constant muscular effort on the part of the man who has to maintain them. No man, therefore, should be kept in one position for any length of time.

The essential points in physical education are gradual progression and individual training, more especially at the start. There is no necessity to coddle men, but there is no necessity to break them down by too rapid advance in the course. Eventually, of course, the soldier must be trained to face severe strain if necessary, and there is no reason why this should not be done even in peace-time if each case be watched.

There is one aspect of physical training which should be remembered, and that is the necessity of some form of exercise, either work or play, if men are to be kept fit. A sedentary army is almost certainly an unhealthy army. Many causes combine, no doubt, to bring this about, but one that is very apt to be forgotten on service is want of exercise. An extract from a letter written by Sir John Moore to Sir Ralph Abercromby is so apropos that I quote it in full. It is dated "Fort Charlotte, St. Lucie, 2nd September, 1796," and runs as follows: "Great attention should be paid in this country to the cleanliness and even neatness of the soldier's person, and the regularity of his

diet ; an addition to the eating part of his ration instead of his rum ; sea or river bathing, constant activity, and movement. In short, General (excuse the pedantry of the expression), but with a Roman, instead of modern, exercise and disclipine, the troops in the West Indies might, I am convinced, be kept healthy. A parade twice a day, consisting of a mere inspection of and exercise of arms, is easy for the officers ; it leaves them what they call more time, but it leaves the soldier also to lounge the whole day in a barrack, where the air cannot be good, and where, from indolence, his body becomes enervated and liable to disorder."

Pringle gives much the same advice. " In fixed camps, as there is always more sickness from inactivity than from fatigue, it would not be amiss to make proper regulations about the exercise at such times ; and the rather that as our soldiers, left to themselves, are naturally too indolent to use what is fit for them "; and he further quotes from the " De Re Militari " of Vegetius the following passage, with which Sir John Moore was also probably well acquainted : " Rei militaris periti, plus quotidiana armorum exercitia ad sanitatem militum putaverunt prodesse, quam medicos, ex quo intelligitur quanto studiosius armorum artem docendus sit semper exercitus, cum ei laboris consuetudo et in castris sanitatem, et in conflictu possit præstare victoriam." The Japanese paid particular attention to organized exercise, chiefly in the form of games, during intervals of rest in their late war.

In peace-time there is little danger of this being forgotten by the British officer, but on service, during periods when the troops are from some cause or another stationary, there is often a feeling that the men should not be harassed, which is apt to be carried too far. Even in cantonments there are always some men who need a certain amount of encouragement to make them take sufficient exercise in the way of games, etc.

There is, however, especially as regards the officer, a danger of going too far in the opposite direction. There is no doubt that many young men do themselves serious injury by immoderate exercise in hot climates. There is no more dangerous excess than that of playing oneself to a

"standstill," as a good many young officers rather exult in doing. It is often remarked in India how often it is the strongest who suffer most severely from enteric fever, and die from it most frequently. A great deal of this is due, I feel positive, to the fact that it is just these men who carry their exercise too far, and who are also prone, from a feeling of false pride, to go on long after they should have given in to the first signs of approaching illness.

This danger of excess was also noticed by Pringle, who remarks : "Some caution is necessary with regard to excess, because our common people generally observe no medium between their love of ease and pursuing the most violent exercise."

CHAPTER V

MARCHING

MARCHING is undoubtedly the most important form of physical exertion demanded of the soldier, since it more than any other comes into direct relation with strategy. As the German Regulations say : " The march forms the groundwork of all operations. The success of every undertaking depends largely on its proper execution, and the arrival of a body of troops in good fighting trim at the proper time and at the appointed place is frequently decisive of the issue." Or, more briefly, in the old saying of Marshal Saxe : " Victory is a question of legs."

It is, in fact, a truism to say that every strategical conception and every tactical plan is based ultimately on the assumption that the flexors and extensors of the lower limbs of a certain body of men will continue to contract and relax normally for a certain period of time. Accurate timing of movements is one of the essential postulates of all staff work in the field, and such accurate timing can only be justified if it is based on a thorough grasp of the principles which underlie the actual physical exercise of marching and the influences which, for good or for evil, affect its economical performance. The question is one primarily of physiology, and must be approached in the first place, therefore, from the physiological standpoint. To begin with, it is necessary to grasp exactly what " marching " means, and for that object I will give the definition which, to my mind, most completely and clearly fulfils that meaning.

" Marching," then, means walking ; wearing certain clothes in a certain manner ; carrying a certain load, disposed on the body in a certain manner ; as one of a unit in a body of men ; at a pace regulated by the average physical

conformation of that body, and not by the personal peculiarities of any particular individual. It is interrupted by periods of rest, termed "halts," the number, distribution, and duration of which are dictated, not by the physical exhaustion of the individual soldier, nor even primarily by that of the body of troops of which he forms a part, but by considerations of a purely strategical or logistic nature. Further, this exertion may be prolonged over periods measured by hours, or even days, and weeks, far beyond any limit that the average man would voluntarily try to attain. In short, in marching we find a communal form of physical exertion, the performance of which is conditioned by no desire or reluctance on the part of the individual, but only by the will of his commander. Seeing that this is so, it is imperatively necessary for that commander to realize what the demands which he makes on the soldier in the ranks by the order to march really are. To arrive at some idea of these, it is necessary to discuss the definition which I have just given in detail.

Walking is the term used to express the ordinary system of progression, in which one foot is always, and both feet for a short time simultaneously, on the ground. This progression imparts a series of movements to the centre of gravity of the body, the most marked of which is, of course, a forward movement in the direction of progression. This forward movement is not at low speeds necessarily continuous, and is never invariable as regards rapidity. On it also are superimposed movements of translation, vertical and lateral in direction. At the same time the whole trunk undergoes certain movements of torsion round a vertical axis, the most marked of which are the swinging in opposite directions of the shoulders and the hips. There is, though less noticeable, a rocking movement of the body at the waist in the antero-posterior direction, and a swaying from side to side, which becomes more marked in case of fatigue. These secondary movements which I have referred to are none of them very great in extent, especially in well-trained men in good marching condition, but with untrained or tired men, and especially when both these states coincide, the cumulative effects of these secondary movements may be important. The actual amounts are given by Du Bois-

Reymond as follows: The centre of gravity has a forward and backward movement in the line of progression, amounting to 12 millimetres (0·48 inch), on either side of a theoretical centre of gravity moving at a uniform rate—that is to say, that in one complete pace of 30 inches the centre of gravity moves 24 millimetres (0·96 inch) forward, and the same extent backwards. The lateral movement amounts to 1·3 centimetres (0·52 inch) on either side of the line of progression, and the vertical to 2 centimetres (0·8 inch) above and below its position at rest. In the aggregate these movements are of considerable importance, and their significance is increased, especially in the case of the vertical movements, when heavy weights are carried. The movements of torsion and rocking are especially concerned with the balance of these weights, though their absolute amount is also to be kept in mind.

The brothers Weber at one time advanced the theory that walking was almost wholly due to a pendular movement of the legs, but this theory is now abandoned. All walking is the result of muscular effort, and the muscles chiefly concerned are naturally those of the legs. The muscles of the upper part of the body are mainly concerned in maintaining the balance of the trunk on the supporting lower limbs, and the extent to which they are engaged is largely a matter of training and of the weight carried. Here, again, fatigue and want of practice in marching, alone or combined, are of great importance. In the lower limbs the muscles used in walking may be classed as "primary" and "secondary." In the first we have actual propulsive movements. The most important of these in this respect are—(1) The muscles of the calf, aided by those of the anterior aspect of the thigh, and to a less extent by the glutei, during the moment when the posterior foot pushes off from the ground, and (2) the quadriceps extensor, which throws the swinging leg forward immediately after it has passed in front of the supporting limb. The secondary muscles of walking are—(1) Those which brace the supporting leg during the time when it alone has to bear the weight of the body, and (2) those which flex the swinging leg so as to enable the foot to clear any irregularities of the road. In the former of these the amount of muscular exertion entailed is entirely dependent on the skill

with which the individual manages to keep his centre of gravity immediately over his area of support, and this again is largely a matter of practice, especially when heavy weights have to be carried. The glutei, in addition to acting slightly to reinforce the propulsive movement of the hindward leg, also have an important action in maintaining the antero-posterior, and lateral balance of the trunk on its supporting limbs. The fatigue of marching in the case of untrained men is largely due to the work of these secondary muscles, and this is most markedly seen when weights are carried.

A form of walking, called *marche en flexion*, has been practised in France which is said by its advocates to enable a man, after a comparatively short period of training, to cover considerable distances at a high rate of speed—that is to say, from five to six, or even more, miles an hour. In this method the legs are kept bent throughout, except just at the moment when the rearmost foot is leaving the ground, whilst the forward foot is planted flat on the ground instead of heel first. The body is bent forward from the hips, but without stooping. This style of walking is imitated from the natural plodding gait of the unshod man, and it is said by its advocates that the individual is dragged forwards by his centre of gravity. "The degree of inclination of the body regulates the pace; if it is desired to go faster the inclination is increased, the legs follow the movement; if the individual desires to check his pace he lessens the inclination. In any case it is never necessary to call on the legs to get an increase in rapidity." The results obtained with picked bodies of men have certainly been extraordinary, and those claimed as possible by the advocates of the system more extraordinary still. It is as well to remember that no work can be achieved without a corresponding expenditure of energy. Energy may indeed be economized, but it can never be created, and it would need very strong proof to substantiate the statement that by merely altering the inclination of the body at the hips it is possible to cover six miles an hour as cheaply as four miles when walking in the ordinary manner. As a matter of fact, a good deal more than this is claimed for the method by its supporters. In reality the system is uneconomical in at least one respect,

since the quadriceps extensor is kept in a state of tension throughout the entire pace, whereas in the ordinary method of heel-and-toe walking it is alternately contracted and relaxed. Richer sums up on this subject : " We are forced to ask whether the results which Commandant Raoul has obtained are not due to special training conditions which he applied to his subjects. As a matter of fact, further experience has by no means confirmed the hopes that were founded on the results first obtained. I understand from Dr. Laveran that the latest experiments have shown that Commandant Raoul's system leads to fatigue, and occasionally to cardiac trouble, and that it has actually been abandoned."

Mere practice in walking alone is not sufficient to teach a man how to march in the ranks, since he is not compelled in the former case to control those secondary movements of his body which lead in the ordinary careless pedestrian to oscillations of greater or less extent on either side of the straight line of progression ; in the ranks these would, if uncontrolled, naturally lead to collision. Again, mere marching in the ranks, without progressive carrying of weights, is insufficient, since the man has not learnt to economize in the matter of those secondary muscular movements which are necessary to maintain an even balance. I have spent some time on these details of the muscular mechanism and the statics of marching, since a good many people seem to hold the opinion that walking, and even marching, come, as Dogberry said of reading and writing, by nature. This is not the case even in the matter of walking, much less in that of marching, and of marching with a heavy load.

So far I have been discussing the physiological mechanism of walking, and it is clear that it consists of a series of complicated muscular movements, repeated at every pace. It is, therefore, a monotonous form of exercise, so monotonous that it is the only form of movement that can, in the case of normal men, be performed even during the sleep of exhaustion. This monotony is accentuated in the case of the marching soldier by the fact that he has to accommodate his movements to those of his comrades, by maintaining a uniform length of pace and a uniform cadence of step. To the trained man this is rather an advantage than otherwise,

since there is no nervous preoccupation necessitated by the constant repetition of the same series of muscular contractions. With the untrained man fatigue sets in sooner, since he has not yet arrived at that stage of being able to march without thinking about it, which results from repeated practice. The most important point, however, in connection with walking is its effect on the general physiological machinery of the body.

Walking is the result of muscular exertion, and the extent of that exertion can be definitely measured by the consequent transference of the individual in a certain direction, horizontal or vertical, or in both directions combined. The amount of work done being known, it is then possible to estimate the exact amount of energy expended in walking any measured distance. The most exact observations in this direction have been made by Zuntz and Schumburg, utilizing the respiratory exchange as a measure of the internal combustion of fuel during any fixed period.

According to these workers, the amount of energy expended per kilo of body weight per metre horizontal varies between 0·0006 and 0·0005 Calories, if the pace be 75 metres per minute. The variation in the amount of energy expended in different cases varies with training, and the mean of the above two figures, 0·00055, may be taken as a fair basis for calculation. Any acceleration above this pace adds 0·0000024 Calorie per metre per minute. From these figures it is possible to arrive at a very close idea of the actual amount of work expended by a man working on a perfectly level plane. The work expended in climbing is equivalent to 0·0075 Calorie per kilo per metre vertical. The following concrete example shows the method adopted for estimating the actual work done on a march. The horizontal distance traversed was 22,032 metres (about 13¾ miles), and the rate 94 metres per minute. The energy expended per kilo of body weight was therefore :

$22{,}302 \times (0{\cdot}00055 + 0{\cdot}0000024 \times 19)$
$= 22{,}302 \times (0{\cdot}00055 + 0{\cdot}000456) = 22{,}302 \times 0{\cdot}000596$, or 0·0006
= 13·4 Calories.

In addition, the vertical height ascended was 182·4 metres (600 feet), and this, multiplied by 0·0075, gives us 1·4 Calories.

The average weight of the men performing the march was 87 kilos, therefore the total work performed was 1,166 Calories in horizontal, and 122 Calories in vertical work, making a total of 1,288 Calories for the whole march. The following figures may be taken as approximately correct for calculating the work done by the average private of the line (weight in heavy marching order, 87 kilos, 191 pounds) in marching one mile at the gradients noted :

1 in 100	.. ..	91	Calories per mile.
1 in 90	.. ..	92	,, ,,
1 in 80	.. ..	93½	,, ,,
1 in 70	.. ..	95	,, ,,
1 in 60	.. ..	98	,, ,,
1 in 50	.. ..	101	,, ,,

From a considerable number of measurements, I find that the roads in the South of England, east of Dartmoor, have, over an ordinary length of march, a gradient of 1 in 100. On Dartmoor the average is between 1 in 70 and 1 in 50. The general average for England would probably be about 95 calories per mile, but for any particular march the actual figure can easily be calculated.

The work done is expressed in terms of heat units, and this follows from the fact that the process is one of combustion, during which heat is actually produced in the body. From this fact several very important corollaries follow.

In the first place, if heat is produced in the body, one of two things must happen—either the heat must in some way be dissipated or the temperature of the body must rise to such an extent that further exertion would be impossible. What actually does happen, in the case of all prolonged exercise, is that the temperature rises to a certain definite point, and there remains stationary so long as the individual under observation is in a normal state of temperature balance. The most important point about this is the fact that the temperature during work is normally raised above the point which in ordinary medical practice is considered the normal temperature. In fact, the expression "normal" temperature is a serious misnomer, unless the occupation of the individual at the time of observation is mentioned. The rise in temperature during exercise is

physiological and beneficial, enabling the muscles to do their work more economically, since the necessary chemical changes are favoured by moderate heat. This is a fact that is recognized in practice, in sport, in everyday life, and in common speech. The regular custom of the preliminary canter in racing is an instance of the former ; the expression " warming to one's work " is an example of the latter. An exactly parallel case may be cited in the internal combustion engine which, as all motorists know, does not run so satisfactorily " cold " as " hot." From a considerable number of observations made by officers going through the Physical Training class at the Royal Army Medical College, I have come to the conclusion that the optimum temperature for walking is about 100·6° F. This level is reached sooner or later after the beginning of the walk, according to personal idiosyncrasy.

It would appear that every man has his normal temperature curve for an ordinary walk. In some this curve rises rapidly and then falls slightly to its permanent level. In others the rise is slow but continuous, and the level is attained later. Various causes influence this curve. Thus, a halt by itself slightly lowers it, especially on a cool day ; whilst the ingestion of food raises it ; the actual curve is therefore a resultant of several factors (see Fig. 1).

In using the expression " normal " curve, it is necessary to appreciate clearly the real significance of this rise in temperature. When we speak of a man at rest having a normal temperature, we mean that his internal body heat is about 98·4° to 98·6° F., and we estimate the importance, pathognomonically, of any rise above that level by the proportion that rise bears to a certain margin of safety, the upper limit of which is marked by a temperature of, say, 104° F. The man still being at rest, we do not consider any rise to less than 102° F. as being of itself a matter of serious import, though its actual significance will depend on various conditions, pathological or otherwise, that happen to coexist therewith. Above 103° F. we begin to feel that the temperature itself is probably beginning to have a deleterious effect, though any serious danger is not to be apprehended as a rule, on this account merely, till a higher level is reached. Ordinarily, then, one may say that a man

at rest has a safety margin of about 4·5° F., inside of which any temperature variation is not of primary importance. In the case of a man taking exercise, the normal temperature is raised probably about 2° F., and this rise is perfectly physiological, and even, as already stated, beneficial. At the same time, the upper-safe limit of temperature is not pushed, so to speak, farther off, but remains unchanged,

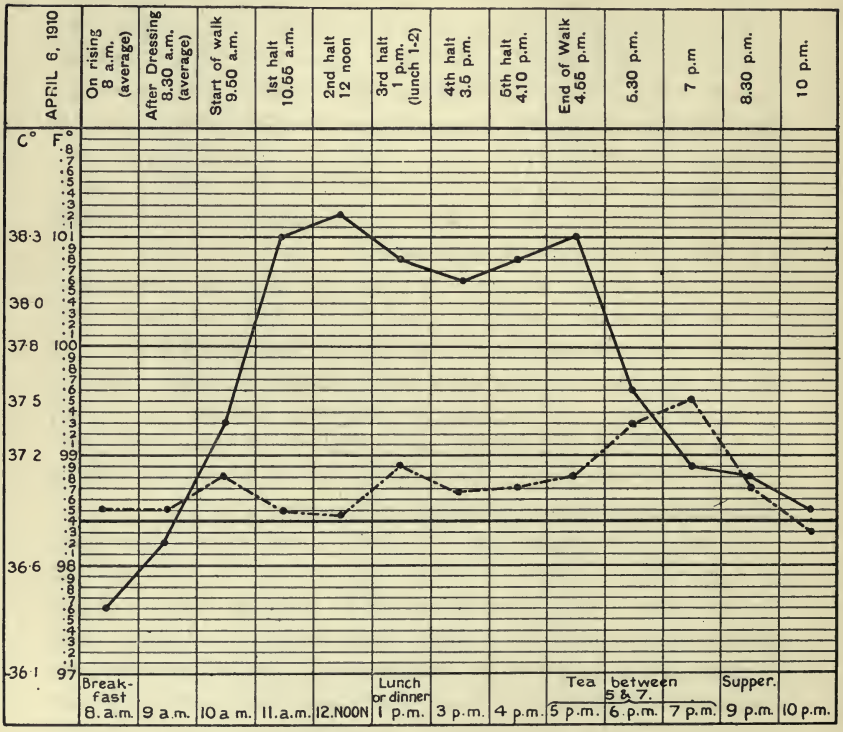


Fig. 1.—Showing Normal Diurnal Range and Range during a 20-Mile Walk.

and in consequence the man at work has a margin of safety of only about 2·5 F., a little more than half that of the man at rest. It therefore becomes most important to study carefully all the causes which may tend to raise the temperature of the man at work above the physiological limit, and thereby diminish to a greater extent the already reduced margin of safety. At any point a man's internal temperature is the resultant of two sets of influences—those that

induce an increased production of heat, and those which favour or impede its dissipation.

The factors which increase the production of heat are chiefly the actual amount of work done, and the rapidity with which it is done. On the other hand, heat can only be dissipated by radiation, convection, and evaporation, and the factors which influence the dissipation of heat must do so by accelerating or retarding one or other of the above-named physical processes. Taking the first-named factors to begin with, it has already been shown that the amount of heat produced is directly proportional to the actual work done, and that it is increased regularly by the rate of work ; in this case, the pace at which the march is performed. This increase is, however, regular only within certain limits. The experiments of Zuntz and Schumburg show that if the pace of 100 metres per second be exceeded, the amount of heat developed per unit increment of pace is out of proportion to that produced at a slower speed, and as the pace increases to an even higher rate so the disproportion is more marked. In the case of the soldier marching, the regulation pace is about 90 metres per minute, though light infantry go somewhat faster than this. The increase due to increased pace is, therefore, not important under ordinary conditions on the march. The most important bearing of speed in this connection is, however, the fact that the pace has to be that of the average man in the ranks, and therefore men markedly below or above the average suffer by having to step out or step short to keep level. In either case the individual is working uneconomically, and the heat production is therefore enhanced. Running, even when the pace is merely that of the " steady double," raises the production of heat considerably, though here again training has an important effect. If the speed be much increased, the body temperature is raised not only on account of the increased production of heat, but also because the time available for dissipation is reduced. In marching this is not, however, a matter of serious importance.

The heat produced is also affected by the load carried. Within certain limits the increment of heat is proportionate to each increment of load, being at the rate of 0·01 Calorie

per kilo per minute as long as the total is under 30 kilos and the weight is evenly distributed. Any lack of balance, however, may raise the expenditure in respect of any particular portion of the load to three times this amount. This point will be again discussed in speaking of equipment.

Other factors which lead to an increased expenditure of fuel are want of training, pain, and fatigue. Training has a most remarkable influence in effecting an economy in fuel expenditure, and by training I do not refer to mere general physical "fitness," but to training in the practice of marching as such. It is surprising what a difference the repeated systematic exercise of this apparently simple series of movements makes on their efficient performance in men who are otherwise in sufficiently good condition. Pain has also a marked effect. Zuntz and Schumburg found that in a man who suffered from inflammation of the tendon sheaths of the foot the expenditure of energy was raised about 20 per cent. The reason of this is that as a result of the pain the normal activity of the muscles ordinarily engaged in propulsion is interfered with, and secondary muscles have therefore to be brought into play, which, being untrained, act uneconomically. The instinctive effort to save a blistered foot would have much the same result. Lastly, fatigue increases the expenditure of energy in proportion to work completed, and therefore also the production of heat. In the chart in Fig. 2 the fatigue-rise in temperature, and its long continuance after work had stopped, is well shown.

As regards the production of heat, therefore, we may conclude that there is a certain normal production of heat for an ordinary amount of work, when a man is fresh and in good condition and practice, that represents for such a man his minimum expenditure of fuel for that particular amount of work. The human engine in its most efficient condition can utilize about one-third of the energy which it actually expends in useful work, showing, as a matter of fact, a much higher degree of efficiency than the best steam-engine yet produced, and one not very inferior to the best internal explosion engine. This ratio of efficiency cannot be improved on, but it may be much diminished by various causes which have already been detailed. Those which are most under our control are training, pain, and

fatigue. By good training not only is the expenditure of energy minimized during an ordinary march, but the onset of fatigue is postponed. Fatigue can also be minimized by reduction of weight, where this is possible, proper arrangement of halts, and other precautions, which it is hardly necessary to enumerate. Pain is chiefly a matter of sore feet. The consideration of this particular point comes later ; it is worth noting here, however, the great importance of

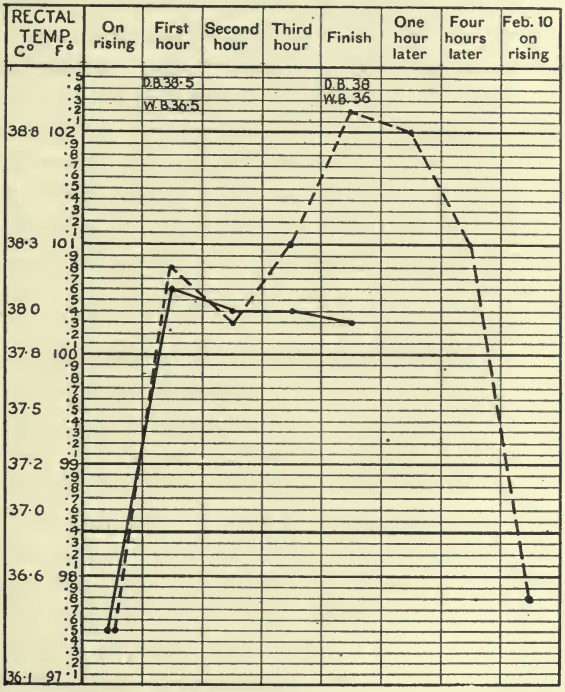


Fig. 2.—Showing Average Temperature-Curve of Four Subjects, 17-Mile Walk (Unbroken Line); Curve of Fifth Subject, Same Walk, showing Fatigue (Dotted Line).

attending to the feet, not merely with a view to reducing suffering, but also with the object of increasing efficiency. It is the duty of every medical officer in charge of a marching unit to assist by his advice the commanding officer in this direction of economizing energy.

Heat is dissipated by convection, radiation, and evaporation. Taking convection and radiation first, it is obvious that heat can only be dissipated in this manner if the

surrounding air, or the other bodies in immediate contact with the body actually under consideration, be at a lower temperature than the surface of that body. In the case of a man this naturally means the surface of his clothes; the uncovered areas of skin come but little into play in comparison. Convection does not come importantly into play unless the air is at a lower temperature than 60° F.; the effect is greater if it is in motion. Still, cold air, especially if dry, is such a bad conductor that but little heat can be dissipated in this way until a temperature of about 50° F. or even lower is reached. If the air be moist and the man at rest, a considerable amount of loss occurs owing to the high specific heat of the moisture in the air. So soon as he begins to move, however, this effect is reversed by the obstruction to evaporation imposed by the high degree of humidity. As regards convection, the movement of the air is the most important factor, within ordinary limits of temperature. Above 65° F. in the shade convection practically ceases under all conditions.

Radiation can only take place from a relatively hot to a relatively cold body. In the case of the soldier in the ranks it is obvious that the nearest bodies are those of his comrades, who are all at much the same temperature as he himself. Radiation can, therefore, have little effect. Evaporation is, in fact, therefore, the chief means by which the body dissipates the heat generated by work, and to facilitate this process by every possible means is one of the primary duties of an officer commanding a marching column.

The extent to which evaporation is available is measured by the degree of relative humidity in the air. All air that is only partially saturated tends to take up moisture from any wet surface, and thereby locks up a certain amount of latent heat, which is abstracted from the surface in question. In man the wet surface is naturally the skin, or the sodden clothes, and it is easy to see that evaporation will be more rapid from the smooth surface of the former than from the rough absorbent hygroscopic surface of the latter. All clothing, therefore, limits evaporation, and thus hinders the dissipation of temperature. How important this effect can be may be seen from some experiments carried out by Dr. Pembrey and Captain (now Major) Parker, R.A.M.C., in

1906, in which a difference of as much as ½ degree was noted as the result of merely opening the drill-jacket on a short march. This simple precaution—namely, that of unbuttoning the coats on the march, is but rarely carried out, and it is the duty of every medical officer in charge of a marching unit to see that this important means of widening the man's margin of safety is brought to the notice of the commanding officer. It is not merely a case of greater comfort for the men, or even of the prevention of disease, though both of these are also concerned, but of increased efficiency at the actual moment. The practice of drilling in shirt-sleeves and "shorts," so universal in India, is worthy of the highest praise from the physiological point of view.

Evaporation can, of course, take place also from the surface of the clothes. The disadvantage here is that the evaporation is delayed in point of time, and when it does happen it is apt to be too late—that is, when the man is halting, or after the march is over, and the increased combustion has ceased. The moisture is then evaporated on a falling temperature, and injury—in popular speech "a chill" —is not unlikely to result.

Evaporation is assisted by the movement of the air, since fresh quantities of non-saturated air are being constantly brought into contact with the free moisture of the man's skin ; still air, or, even worse, a gentle following wind, have a repressive effect on evaporation. I have already stated that all air that is only partially saturated tends to take up moisture from any wet surface, and, conversely, a saturated air can take up no more moisture. Air is able to hold greater quantities of water vapour at high temperatures than low, and, therefore, for the same degree of absolute humidity hot air is more favourable to evaporation than cold. The degree of relative humidity is measured by the difference between the wet and dry bulb thermometers, and for any one fairly uniform climate the reading of the wet-bulb thermometer can be taken as a fairly safe criterion of the amount of relative humidity. In England, for instance, a wet-bulb temperature of 75° F. indicates a relative humidity approaching so nearly to saturation that evaporation is almost impeded, and exertion very difficult. In India, on the other hand, a wet-bulb temperature of 86° F. is tolerated with

ease, and exercise can be enjoyed if only the dry bulb is sufficiently elevated to show a reasonably low relative humidity. It is important to remember that the absolute temperature, either that of the wet or dry bulbs, is not the really important point. The capacity of the air to take up additional moisture is the essential consideration, and where this is small or absent, the fact that the air temperature is comparatively low will not prevent the body temperature rising to a serious extent. On the other hand, a dry-bulb temperature of 110° F., or even higher, is consistent with active exertion if only the relative humidity is so low that the air can take up moisture from the body to a sufficient extent. Anyone who has served in India knows the difference between the bracing influence of the heat during the earlier months of the hot weather and the enervating effect of a " muggy " day in spring or autumn in England. It is important, therefore, that officers in charge of troops should watch carefully during the drill season the variations in relative humidity, since on these the amount of work that can be demanded of the men depends.

Evaporation is affected also by the fact that men have to march in organized bodies more or less close to each other. The evaporation of the moisture from the breath and skin of the men at the head of the column raises the relative humidity of the air breathed by the men farther to the rear, and thus interferes with their heat regulation. This disadvantage can be lessened, or rather distributed, by opening out the ranks, and changing the order of march. In a hedgerow country like ours the difficulty is greater than in a less enclosed terrain ; still, it is doubtful if advantage is taken as often as might be of open spaces when they do occur. Deep cuttings, such as occasionally occur on chalk and limestone downs, should be avoided by a detour, if possible. It has already been shown that direct radiation and convection can play but little part in assisting the dissipation of heat under ordinary conditions. They may, however, work strongly in the opposite direction on occasion. A hot sun shining on the surface of the clothes may heat these to such an extent as to increase actively the internal temperature. Whether rays other than the heat rays do of themselves exert any actinic effect on the constitution is a matter about

which there has been much discussion. A series of observations made lately in Manilla by officers of the United States Army would appear to point to the conclusion that the actinic rays exercise no injurious effect, but the conditions under which the experiments were carried out were, in my opinion, hardly such as to furnish a final answer. The occurrence of cases of what Weiss terms *coup de soleil électrique* is sufficient proof that intense light rays have a certain effect on the nervous system, whilst the common experience of "snow blindness" amongst mountaineers, and of "sunburn" from exposure to the ultra-violet rays, point to some as yet unanalyzed action of these forms of radiant energy. Personally, I feel inclined to maintain a non-committal attitude, and as regards prevention am in favour of, and should personally practise, the use of coloured fabrics in the clothing, more especially in the lining of the headgear, until more definite proof is brought forward of their inutility.

The Effects of Profuse Perspiration.—Since, as already stated, the regulation of the temperature depends almost entirely on evaporation of moisture, it is obvious that during severe exertion profuse sweating is necessary to provide the means for this evaporation. A certain amount of evaporation doubtless occurs from the moisture exhaled by the lungs, but the amount of this is constant, and cannot be increased in the same ratio as that exuded from the sweat glands. It is on these last we have therefore to rely. The well-known case related by Zuntz and Tendlau, in which there was congenital absence of sweat glands, and the subject was enabled to work during hot weather only by freely soaking his shirt in water, is the best illustration of their importance. But if this mechanism is to be made use of it is obvious that a considerable loss of water from the body must result. In the experiments of Zuntz and Schumburg on one occasion as much as 3,366 grammes (7½ pounds) of water were lost, of which about seven-eighths were evaporated, and the balance (420 grammes) remained in the clothes. In some experiments carried out by Pembrey and Parker at Aldershot in 1906, the average loss during a seven-mile march was 1,129 grammes, of which 137 grammes remained in the clothes.

The significance of these two facts is considerable. To take the second first, the retention of a certain amount of water in the clothing is an illustration of the point raised some little while back as to the effect of clothing on this means of regulation of the temperature. It is obvious that this amount of water was on these occasions lost to the body without any corresponding advantage being reaped, and again, that the subsequent evaporation of this amount of moisture would deprive the body of a certain amount of heat at a time when there was no longer increased combustion going on to replace the loss. In a case like that noted above, where 420 grammes of water remained in the clothes, this would represent a loss of over 200 Calories to a body that was already cooling down.

The actual loss of water is in itself, however, a matter of paramount importance. The total amount of water present in the body of a 10-stone man is equivalent to about two-thirds of his total body weight—93 pounds, or rather over 9 gallons. Of this it is dangerous for him to lose as much as one-tenth, and any loss approaching one-twentieth must be replaced at a fairly early moment if efficiency is to be retained. In the above case, quoted by Zuntz, the limit is nearly reached, and some of Pembrey's figures are not far behind. It is obvious, then, that if a man loses as much water as is recorded in the above observations, he must replace the loss by drinking. This fact has to be very clearly recognized, since it lies at the root of all successful march discipline in warm weather. In the German Regulations this is the case, and it is worth while quoting the paragraph relating to this point in full:

"The greatest enemy of infantry on the march is heat, and special measures should be taken to protect the men against this, which is one of the most important causes of depletion of the ranks. The best means at our disposal is careful regulation of drinking. Mounted officers or bicycle orderlies should be sent on ahead of a column to warn the inhabitants of villages to turn out and have water ready on both sides of the road for the troops. If possible a halt of short duration may be made for this purpose, otherwise, if time presses, the men must snatch a drink as they pass, and, if possible, fill their water-bottles."

During a twenty-four hours' walking race carried out at the Stadium in 1909 the competitors, following the usual custom, limited more or less strictly their allowance of water. They all suffered somewhat severely from abdominal pain, and in some cases vomiting occurred, owing to the fact that there was an insufficient supply of water in the body to permit of a satisfactory secretion of gastric juice. In an interesting correspondence in the *British Medical Journal*, which followed the publication of the report on this contest, the necessity of a liberal supply of water during severe exertion was insisted on by several writers, one of them (Dr. Claude Wilson), an experienced Alpine climber, quoting a saying of a secretary to the Alpine Club, to the effect that "the more you drink the further you go." An interesting illustration of the same principle is afforded by the practice of the General Omnibus Company with respect to the watering of their horses in hot weather. The Company has found by practical experience that a liberal allowance of water, both for drinking and washing down, is a remunerative step, and accordingly they supply this at various places on their omnibus routes. At the same time, we must recognize the danger of allowing men to drink from any and every source, and even such a comparatively orderly method of procedure as that already related from the German Regulations is not free from objection.

The key to the solution of the problem lies in "discipline." If discipline is to be enforced in the matter of so imperious a natural appetite as thirst, the conditions must be thoroughly grasped. In the first place, then, we must lay down that no man shall drink water from his water-bottle, or elsewhere, except by the order of his officer. The standing order of the Light Division in the Peninsula is the best guide here; it runs as follows:

"Section 2, article lv., 3: The officers must be particularly attentive to prevent the men going out of the ranks for water; when this is required the battalion or brigade must be halted."

If this order is to be obeyed the officer must know exactly when it is necessary to allow water to be drunk, and this can be ascertained in two ways—either by relying on the sensations of the men, or by a scientific calculation. The

first-named, which is the best, can only be safely used if the men are so trained that their subjective sensations can be relied on as evidence. The subjective sensation of thirst in the untrained man is merely an expression of a parched condition of the mucous membrane of the mouth and pharynx ; in the trained man it is, or should be, the expression of a water-hunger in the active tissues generally. Unless the man is trained to such an extent that he is able to disregard the former, which we may call " the thirst of habit," it is impossible for him to know by the evidence of his sensations when the latter stage, the real " thirst of necessity," is reached. This training should be carried out naturally in the ordinary course of military instruction. It is, in my opinion, one of the most valuable items of training in the whole course. It is also possible to arrive at a fairly accurate idea of how much water is needed and when, by estimating the probable water loss on scientific grounds. Presupposing that the conditions are such that heat regulation can be carried out only by evaporation, we know that the evaporation of 2 grammes of water will abstract about 1 Calorie from the body ; therefore, if we know the amount of work done, we know the amount of water that must be evaporated to maintain the body temperature at a constant figure. Taking the average energy expenditure per mile at 90 Calories, this infers an evaporation of 180 grammes of water per mile. One litre will therefore be evaporated in about six miles. During the earlier part of the march, however, the heat is allowed to accumulate in the body to raise it to the normal marching temperature, and therefore evaporation will not come into the question until this point is reached. Taking the specific heat of the body as 0·83 and the optimum marching temperature as 1·2° C. above the optimum at rest, it is obvious that it will take about three-quarters of a mile to raise the temperature of a 10-stone man (63·6 kilos) to this extent. Evaporation will therefore presumably come into play as soon as this distance has been covered. It is not, however, necessary to replace the lost moisture at the very instant of evaporation, and it is permissible to suppose that a man can safely lose about one-fortieth of the water in his body without inefficiency resulting. This gives us a margin of $1\frac{3}{4}$ pints, or 1 litre,

equivalent to a distance of about six miles. The corollary, therefore, is that if temperature regulation is dependent purely on evaporation, then under ordinary conditions a man should not need to touch his water-supply till about seven miles of an ordinary give-and-take road have been covered, and that after this he should be allowed 1 litre, which is equivalent to $1\frac{3}{4}$ pints—in other words, the contents of his water-bottle—every six miles. Under specially harassing conditions more latitude should be allowed, but it is a safe rule to lay down that on an ordinary march of fourteen to sixteen miles no man should be allowed to touch his water-bottle till the half-way halt, and should not empty it till within a mile of camp. Such a rule does not make any extraordinary demands on a man's endurance, and is, I believe, enforced in some regiments. That it is not enforced in all I have had ocular proof from watching men on manœuvres. In short, water on the march should be treated with as much care as ammunition. Just as no man may expend a round of the latter without authority, so no man should expend a drop of the former without the same authority. "Water discipline" is as essential to good marching as "fire discipline" is to good fighting, and I would venture to say that a unit in which the former cannot be enforced (as one sometimes hears it said, especially in this connection, "The soldier won't do this," or "It is no use expecting him to do that") is a unit in which the latter is unlikely to be observed. After all, whatever prefix one may attach to the word, there is only one "discipline," and that is obedience to orders.

Pathological Aspects of Heat Production on the March.—If from any cause the production of heat in the body exceeds a certain limit, or the dissipation of heat fails, then the result is a condition of pyrexia. The permissible range is fairly high. The optimum being, say, 100·6° F., my experience is that no serious effects are likely to result as long as the temperature does not rise above 102° F. Any further rise is pathological. The most marked early effect is seen when the man is halted. He is unable to stand steady, but sways slightly, and his hand becomes tremulous. The face is flushed, and the eyes inclined to stare. The skin is sensibly hot to the touch, the respiration laboured, and

the mouth open. Later, the skin may become cold and clammy as the result of exhaustion, the lips being cyanotic, but in strong young adults the usual result is increased flushing, with injection of the conjunctivæ. The ultimate stage of this condition is heat-stroke. The causes of this condition have practically all been already detailed. The classification given by Hiller is perhaps the best, just as his study of the subject has been the most complete. He arranges them under three heads, as being connected with (1) the weather, (2) military duties, and (3) individual predisposition. Amongst the meteorological causes he places first high-air temperature, the majority of cases being recorded in the months of June, July, and August, and at readings between 77° and 88° F. (dry bulb). A high degree of relative humidity comes next, followed by stillness of the air, and direct exposure to the sun's rays, heating up the clothing and accoutrements. Causes connected with military duty are the hour of the march, the formation adopted, omission to open the clothing, the number of halts, weight of accoutrements, and the selection of the force. As regards the hour of the march, he states that 80 per cent. of his cases occurred between 10 a.m. and 3 p.m., and recommends that short marches should be so timed as to finish before the first-named hour. In the case of long marches, a substantial midday halt should be followed by the completion of the march in the cool of the evening. No one who has served in India will need much instruction on this point. It is important, however, to remember that it is possible to fall into the other extreme, and start too early. The pestilential old Indian custom of starting at 2 a.m., even in the cold weather, which ruined the men's rest, and exposed them, tired and unfed, to the rays of the early morning sun, striking under the helmet brim, was as irrational as starting too late at the hotter season of the year. As regards the selection of the men, this involves the exclusion of all men who suffer from a personal liability, whether that be individual and of a permanent nature, or the result of antecedent illness, or the nature of the occupation. Individual predisposition includes the influence of the occupation and life of the soldier on his general muscular fitness, and the presence of certain organic abnormalities.

Amongst habits and occupation, the most important place is held by those which tend to produce muscular inactivity. Reservists, men on the active list told off as cooks, or clerks, or who had suffered long terms of imprisonment, or had lately left hospital, supplied the great majority of the cases. The remainder occurred in men whose general bodily constitution was temporarily or permanently weakened, as in the case of hard drinkers, men prone to over-eating, or suffering from digestive disturbance. Insufficient sleep accounted for 6 per cent. of the cases, a point worth noting in connection with men employed on picket or guard, or orderlies in attendance on cases at night. Want of food, as conducing to general weakness, also exercises an important effect. Organic disease accounts for a comparatively small number of cases, though the mortality of such as are due to such conditions is exceptionally high. Adhesions of the pleura occurred in 36 per cent. of Hiller's post-mortems. Disease of the circulatory and urinary systems were comparatively rare, probably as being less likely to escape notice during ordinary life. Excess of adipose tissue, whether general or confined to the heart, was present in a large number of cases.

The prevention of heat-stroke lies in observing, and as far as possible minimizing, the causes which produce it. The only cause which is absolutely beyond control in any way is the high relative humidity of the air. The absolute heat of the day, and exposure to the sun's rays, can be avoided by a judicious selection of the hour of marching, the stillness of the air minimized to a certain extent by opening the ranks. All the other causes above detailed are under the control of the commanding officer, and he and his immediate medical adviser should be held responsible that they are guarded against.

Effects of Marching on the Respiration, Circulation, and other Systems of the Body.—Marching, being a form of muscular work, entails, as already shown, a certain amount of combustion proportionate to the energy actually developed in the production of the work. This combustion demands an increased supply of oxygen, and an increased supply of fuel, and leads, therefore, to an increase in the respiratory exchange, and an acceleration of the circulation.

It therefore affects importantly both the respiratory and circulatory systems. Again, since the regulation of the temperature is effected largely by evaporation from the skin, the composition of the blood and the functions of the urinary system are also interfered with.

Effects on the Respiratory System.—The demand for an increased supply of oxygen is met at first by an increase in the number of respirations, and, later, by an increase in their depth, the former change being, however, the most marked. Any cause which leads to greater combustion obviously entails also increased respiratory exchange; therefore load, pace, and the other factors already detailed when considering the question of combustion need not be again discussed. The most important point to remember is the necessity of keeping the movements of the chest as far as possible unhampered by any constricting bands, which might interfere either with the rapidity or the magnitude of its movements. Here, again, it is necessary to insist on the absence of all straps crossing the chest above the waist. It is impossible, with any form of equipment, to avoid entirely some interference with the chest movements. As long as a man has to carry some of his belongings on his person, and at the same time keep his hands free for fighting and his legs unencumbered, it is obvious that the weights so imposed on him must come into direct relation to his chest wall, and must take part in every movement of that wall. The ill-effects can be minimized by a suitable arrangement of the different weights forming the load, a point that falls to be considered under the heading of Equipment.

Increase in weight carried diminishes to a serious extent the " vital capacity," and this diminution will affect naturally the " complemental air " to the greatest extent. The " tidal air " will also share in the reduction, especially after fatigue, whether general or affecting only the respiratory muscles, has set in. Zuntz and Schumburg give a reduction of vital capacity of about 9 per cent. with a load of 22 kilos (48·4 pounds), of about 11 per cent. with a load of 27 kilos (59·4 pounds), and about 12 per cent. with a load of 31 kilos (68·2 pounds). In individual cases the reduction was much greater, amounting in one subject, with the minimum weight, to 18 per cent., and with the maximum to 25 per cent. of the

vital capacity at rest. Practice in the carrying of loads is most important in this connection. Schwiening recommends the use of breathing exercises (*Lungengymnastik*) for this purpose. Loath as one naturally is to disagree with such an authority, I cannot help feeling that this suggestion is in direct opposition to sound practice. A man will soonest get accustomed to carrying loads by carrying them. The respiratory system is not the only one concerned in the matter, and though breathing exercises may doubtless strengthen the chest muscles and so enable them to compete with an increased load, the legs and those parts of the trunk which have to bear the actual pressure of the loads will not in any way benefit by these exercises, and will demand some other special form of training. It cannot be too often repeated that the best way to learn how to do a thing well is to do it, and the best way to keep in good condition to do it well is to go on doing it.

When the embarrassment of the respiratory movements becomes serious, the usual sequences follow—namely, engorgement of the bases of the lungs, obstruction to the flow of blood through the right side of the heart, and through the liver. These last are indicated by an increase in the cardiac and hepatic dulness. Zuntz and Schumburg report such an increase in 56 per cent. of cases when the load was 22 kilos, 70·4 per cent. when the load was 27 kilos, and 87·5 per cent when it reached 31 kilos. The liver acts, according to these observers, as a safety-valve to the heart, dilatation of the former organ occurring earlier than that of the latter. The dilatation affected the right side of the heart practically in all cases, and in half the left was also affected. It was noted that these phenomena coincided with an increased respiratory rate, and an increase in body temperature, and were largely due to the constriction imposed on the body by the waist-belt and the weight of the cartridge pouches. They did not appear to bear any relation to the pulse-rate.

The changes in the outlines of the cardiac and hepatic dulness noted above disappear, as a rule, in a healthy, well-trained man in the course of two or three hours, or at least by the evening of the day on which the exertion was incurred. Occasionally, however, the effects are more lasting, and persist until the next morning. It can easily be understood

that in cases like these last named important digestive disturbance might result, and a man so affected would not be in a condition to repeat the exertion on the following day. The chief practical point in this connection is, in my opinion, the tightness of the waist-belt. In the majority of equipments the position of this band depends largely on the balance of the accoutrements. If, as is often the case, it tends to be drawn upwards, the resulting constriction will affect the liver very seriously. In the new webbing equipment, when ammunition is carried, this is not the case, and if the belt be worn loose no ill-effects need result. Worn tight, with the weight of seventy-five rounds applied closely over the hepatic region, it may exercise a distinctly injurious influence. In the new American equipment the belt is allowed to sag downwards almost to the line of Poupart's ligament.

Effects on the Circulation.—The increased combustion, demanding, as it does, increased oxygen and increased fuel, naturally entails an increased acceleration of the cardiac rhythm. This is very marked, the pulse responding almost at once to any alteration in position or pace. The pulse-rate is more variable during exercise than either the respiratory rhythm or the temperature, and can easily be doubled by a smart run. The increase during an ordinary march is from 40 to 100 per cent. of the rate at rest. It is dependent on, primarily, the same conditions as those which affect the combustion ; these have already been detailed, and need not be again repeated. The essential nature of the relationship is apt to be masked by secondary influences, affecting the lumen of the peripheral circulation.

When the heart has to beat more rapidly, it shortens the diastole to a greater extent than the systole, so that the ratio between these two periods, which may be taken as being under normal circumstances about 3 to 1, may fall as low as unity, or even below this figure. The corollary of this is that the heart gradually gets less time to become filled with blood, and its driving power is to that extent lessened. That is to say, each successive beat sends out into the systemic circulation a gradually diminishing volume of blood. The effects of this diminished efficiency in the direction of reducing the supply of fuel and oxygen to the muscles need not be dilated on.

The first effect on the blood-pressure is to increase it. This is due to the fact that the *vis a tergo* of the heart-beat is increased, whilst the resistance of the circulation through the cutaneous capillaries is at first maintained at normal, and that through the capillaries of the muscles increased by their contraction. As the skin becomes warm, the capillaries and smaller arterioles near the surface dilate, and the pressure may fall to normal or remain but slightly higher than this as long as the exercise persists. Any weakening of the heart-beat will, in consequence, now lead to a fall in the blood-pressure, due to the diminished drive of the heart. In fatigue this occurs, and the pressure may fall so low that the heart can no longer keep the superficial capillaries full. The skin then becomes clammy and pale, and the lips show by their colour the deficient aeration in the lungs. Ordinarily, especially in well-trained men, the changes in the circulation are so transient that they pass off in the first minute or so of halt. They are therefore best investigated by the simple clinical method of palpating, and counting the pulse. It is only in the more serious cases that circulatory disturbances persist for any length of time.

The effects produced on the blood are an increase in the specific gravity, and also in the number of red and white blood corpuscles. The first named is not great. Zuntz and Schumburg report an average advance of the specific gravity from 1059·6 to 1063. The red corpuscles increased by 9 per cent., and the white by 43 per cent. The rise in specific gravity is attributed chiefly to an increased osmosis into the active tissues, the result of the presence therein of metabolites ; loss of moisture from perspiration must also have some effect. The increase in the red corpuscles is probably only relative, but that of the leucocytes is an actual multiplication due to the washing of corpuscles from the walls of the larger veins by the more powerful flow of the blood. The change affects chiefly the large polynuclears, and is more persistent than the others just noted, which are transient in their nature. The increased specific gravity of the blood is of importance as being likely to interfere with the free perspiration demanded if heat regulation is to be satisfactorily maintained.

Effects on the Urinary System.—The specific gravity of

the urine may be raised or lowered by the march, and the exact conditions which determine either result seem to be as yet unsettled. Zuntz and Schumburg came to the conclusion that the exertion of the march had a positively diuretic effect, causing the excretion of a more dilute urine even on days when there had been profuse sweating, and but little fluid had been drunk. Albumin occurs not infrequently in the urine after severe exertion, and it is still doubtful in how far this is to be considered pathological. It undoubtedly shows itself amongst even well-trained men. Collier reports its presence in 130 out of 156 rowing men actually in training, and in them has been attributed to deficient oxygen-supply to the kidneys during hard work, the demands of the active muscles having first to be met. In all probability the safest line to take in such a case is to judge by the concurrent symptoms present. Albuminuria in a man not previously known to be in the habit of passing albumin should always lead to careful watching of the individual. If persistent, or if accompanied by casts or other signs of disordered metabolism, it should undoubtedly be looked upon as a serious condition. In any case, it must be taken as a possible danger-signal until proved to be the contrary.

Halts.—The proper distribution of halts and their duration exercises a great influence on the marching powers of the men. In Field Service Regulations, part i., p. 47, it is laid down that a short halt will be ordered soon after the column has started, subsequent halts being arranged at the discretion of the commander of the column. The early halt is a general practice, and its object is explained in the German Regulations as being to adjust clothing and accoutrements, and meet the calls of nature. After an early start this halt is extremely important, and should not be curtailed. Subsequent halts must be made according to the condition of the men, the state of the weather, etc. As regards the condition of the men, it is important to remember that the men who count are those at the rear of the column, where the air is saturated and the dust most trying. The duties of the commander naturally keep him at the head of the main body, and he is apt sometimes to forget how very different the air at the farther end of his

column may be from that which he himself breathes. The medical officer in charge of the rearmost infantry unit should be made responsible for notifying the effect of the march on the men he is in charge of to the commanding officer of that unit, and suggesting a halt or change of position if necessary.

The usual practice is to halt for five or ten minutes at the end of every hour, with a longer halt a little beyond half-way, of, say, half an hour. The French take ten minutes' halt after every fifty on the road, with half an hour after being three hours on the road, or after three-quarters of the total distance has been covered. The Germans seem to be less lavish in this particular. General Stonewall Jackson ordered a halt of ten minnutes every hour; the Light Division in the Peninsula took two halts on a twelve-mile march.

From a physiological point of view, a halt should either be short or decidedly long. Ten minutes is, if anything, too long for a short halt, as with a tired man it gives him enough time to get stiff, but not long enough for a thorough rest. Under ordinary marching conditions, the hourly halt is in reality only necessary to break the monotony of the march, and to mark the lapse of time. It also affords men time to adjust boot-laces, get rid of small stones that may have got into their boots, and so on. For this purpose five minutes should be enough. If a longer halt be made, then at least half an hour should be allowed. The men should take off their accoutrements, and, if possible, lie down. In an enclosed arable country this last may often be impossible, but in open country, or where the bulk of the land is under pasture, there need be no difficulty. Heavy rain and soaking grass might, it is true, prevent it, but the mere fact that the grass is damp need not. If necessary, the men can take their greatcoats out of their packs and put them on, or use them to lie down on. In the Light Division the custom at each of the two halts already alluded to was to take off packs and lie down, each company resuming the packs only just in time to admit of its marching off at the proper moment. Stonewall Jackson used to say, "A man rests all over when he lies down."

From a physiological point of view, I think it important

to emphasize the difference between the halt that is merely, as it were, a punctuation in the course of a march, and the halt that is a real rest. The former should never be more than ten minutes, and five is better ; the latter never under half an hour, and an hour, if the time can be afforded, is preferable. The place where the long halt is to be made is of importance. In very hot weather shade, unless it be accompanied by fresh air, is not always an advantage, especially in this country. The direct rays of the sun are less likely to hurt than the close, damp air of a wood. Where a road is heavily wooded on both sides it is better to push on and get into the open before halting. The foot of an ascent is a bad place to stop at. Physiologically, the rest will be more appreciated at the top of a hill, when the pulse and respiration are both accelerated ; in addition, the ascent will be less easily tackled immediately on starting after a prolonged rest, owing to stiffness, and the fact that the men need to be warmed to their work.

Forced Marches.—This term is applied either to one severe march or to a succession of long marches prolonged over several days. Classical examples of the former in our army are the magnificent march of Marlborough's troops—40 miles in eighteen hours—through Villars' lines, in 1710 ; the march of the Light division to Talavera in 1809—62 miles in twenty-six hours ; and the march of the same body after Sauroren in 1813—40 miles over mountain-roads in nineteen consecutive hours.

The two famous marches carried out by Lord Roberts from Cabul to Candahar—318 miles in twenty-three days—and from Bloemfontein to Pretoria, during which his central column marched 300 miles in thirty-four days, and that commanded by Sir Ian Hamilton—384 miles in thirty-seven days—are our best-known modern examples of the continuous forced march.

These different types of forced march have a very different significance from the point of view of the physiologist, and therefore of the sanitarian. In both cases the human machinery is exposed to a tremendous strain, but whereas in the first case this is concentrated into a few hours, in the latter it is spread over a period of days or weeks. In either case this strain will probably lead to a considerable thinning

of the ranks, but the measures to be adopted to lessen such thinning will differ considerably in the two cases. In the case of the single severe march the demand for energy is rarely greater than can actually be supplied in the form of food, or, in other words, fuel. For instance, in the case of the Light Division marching to Talavera, if we take the average energy expenditure per mile at 150 Calories—that is, more than half as much again as would be needed in the southern counties of England—it would be necessary to supply each man for his sixty-two miles with 9,300 Calories of food. It is quite simple to devise a ration which should supply this amount of energy in a weight of 7 pounds, and still contain 50 per cent. of water. There would be no insuperable difficulty in lowering this weight to 4 pounds, by using desiccated food, which the man could easily carry on his person. But, after all, there would be no necessity for supplying so much additional energy as this, since any man can live for a certain time on his own tissues. It would be fair to expect a supply from this source of at least 3,000 Calories. The difficulty lies not in the question of fuel in short, but, adhering to the same metaphor, in that of lubrication. The prolonged exertion demands an excessive excretion of water, and unless this is replaced the tissues get blocked by their own products of disintegration, and the machine becomes clogged.

Napier's description of the men during the march after Sauroren, when many "fell and died, convulsed and frothing at the mouth, while others, whose spirit and strength had never before been quelled, leant on their muskets, and muttered in sullen tones that they yielded for the first time," answers exactly to the description by Hiller of the dyscrasic-paralytic form of heat-stroke, which "affects most severely, as a rule, the most trustworthy and stout-hearted men, who would never of their own free-will leave the ranks," and which is characterized, amongst other symptoms, by "severe general muscular spasms, with rigid opisthotonos, clenched jaws, and foaming at the mouth." Such a condition can only be guarded against by a free supply of water. All other precautions, lightening the weight carried, opening the jackets, and so on, must also be taken; but unless the blood is in such a state that it can flush out the working

tissues, and remove the waste products of exercise, any other measures will be purely palliative. I have already stated the amount of water that a man requires for a short or ordinary march. For a long march he should, in my opinion, be allowed his water-bottle full at every sixth mile after the conclusion of the first eight or so. That is, starting with the water-bottle full, it should be replenished at the fourteenth, twentieth, twenty-sixth mile, and so on. I cannot see that in any civilized country this need present any insuperable difficulty, though it does, of course, demand forethought. In such a case there must be no meticulous haggling over the question of quality—water the men must have, the best that can be procured, but water in any case.

Before undertaking such a march, staff and medical officers should study carefully on the map the possibilities of getting water on the road, and in this direction a knowledge of geology will be of the greatest value. Success—that is to say, the number of efficient men that the commander can place at his objective point—will depend on the amount of water that he procures for his men *en route* more than on any other one physical condition. Deficient water may not mean absolute failure—that is to say, with bad arrangements, or even without any arrangements at all, some men will arrive at their destination. They will be fewer in numbers, and less efficient in quality, than if reasonable provision is made. Inefficient lubrication of an engine may go far before actual "seizing" occurs, but the bearings suffer nevertheless, and the case of a badly watered army is precisely similar.

As already stated, this water is needed to further the processes of metabolism, and also to free the muscles from the waste products that otherwise will accumulate in them. This last object may be materially assisted by the practice of massage at the halts. I am indebted for this hint to Colonel Mark Sykes of the 5th Battalion, Yorkshire Regiment (T.F.). It consists in forcible flexion, followed by forcible extension of each leg three times, every joint being moved to the utmost possible extent, after which the legs and buttocks are kneaded firmly. This procedure has a marked effect in reducing cramp at the time and stiffness subsequent to the march.

The continuous forced march stands on a different physiological footing to the single severe effort. In this case the exertion on any one day is not peculiarly exhausting. Thus, in the Cabul-Candahar march the average distance traversed each day was only 13·9 miles if the whole period be included, or 15·14 miles if marching days only are taken into consideration. The average daily distance traversed by General Ian Hamilton's force between Bloemfontein and Pretoria was just over ten miles, that of Lord Roberts' centre column eight and a half miles. If only marching days are counted, these figures rise to a little over thirteen, and to sixteen and a half miles respectively. The longest march performed by the first-named force was twenty-eight miles, and by the second twenty-two miles. Obviously the actual exertion demanded of the men was not on any one day a serious matter. The effects produced by such a march are not, therefore, due to the severity of the work, but to the constant repetition of a strain that is perhaps just slightly above the average of that to which the bodily mechanism of the soldier is accustomed. This is fairly obvious if we consider the history of such marches in the past. In 1805 the Grand Army which Napoleon had collected at Boulogne for the projected invasion of England marched from that town to the Rhine, 400 miles, in twenty-five days. The men were seasoned soldiers who had been assiduously trained for a great adventure for many months, and their losses were in consequence small. On the other hand, the force which marched from the north of Germany to Vienna in 1809, composed largely of young men recruits, left a substantial proportion of its numbers on the road. More than one-half the men composing this army were under twenty years of age. In the march to Candahar the only regiment which suffered seriously was the 72nd Highlanders, which contained a large draft of men who had arrived lately from Scotland. The seasoned infantry which followed Lord Roberts to Pretoria lost only 4 per cent. of their strength. Training, then, is the most important factor in the performance of the continuous forced march. Next to training comes food, or, in other words, fuel. For any prolonged exertion of this nature a special addition to the ration is advisable. This addition should consist of some

easily digested and assimilated foodstuff, and, personally, I consider that sugar is the most suitable form which it can take. The fats, though their energy value is so much higher, are not so easily digestible, and beyond a certain point are not assimilable. Protein is less digestible, and I should be averse to increasing the already high proportion of this food principle present in our ration. I would, however, make an exception in favour of including meat extractives in the ration. These have no energy value of their own, but their power of stimulating the digestive powers is very great, and for a tired man a mess-tin of hot soup, even if made from tinned extract, may act as what our Elizabethan ancestors were in the habit of calling a "shoeing horn" to the less attractive but more solid components of the ration. Alcohol might also be more freely used on a march of this nature than under ordinary conditions. The opportunity for its use would arise at the end of any particularly harassing day, to encourage the men to make themselves comfortable for the night. The occasions should be carefully chosen, since the issue would lose much of its value if it came to be looked on as a regular custom instead of being an exceptional resource.

Care of the Feet.—So far I have discussed chiefly the physiological principles on which the performance of the march is based. Anatomically, it is concerned chiefly with the foot of the soldier, and mainly with the skin of the foot. The actual formation of that limb is a question for the recruiting officer, and any defect in that direction must be remedied before the question of marching comes into consideration at all. There is only one word that I should like to say here in favour of exercising a certain amount of moderation on the consideration of this point. The modern human foot is the result of the use of artificial foot-gear, lasting over many generations. When we consider the question of walking as it affects civilized man, we must consider the foot as consisting of a foot plus a boot. We can no more leave the latter out of consideration than we can set on one side the man's clothes when we discuss the question of temperature regulation. The naked, bare-foot savage is one person, the civilized man, booted and clad, according to the customs, senseless or otherwise of his race,

is another, and it is the latter with which we have in practice to deal. Whether a reform in the foot-wear of the nation is possible or necessary is not for the army medical officer to decide. He must take the booted foot as he gets it, and make the best of it. The important point for him to consider is the junction between the foot and the boot—that is, the interaction between the inner surface of the leather of which the former is composed, and the skin with which the latter is covered. This interaction is controlled by the interposition of the sock or other form of foot-covering in use, and the general question of the construction of these, and also of boots, will be touched on under Clothing. Here I wish only to refer to the feet themselves. If the foot be normally shaped, within the usual variations met with in civilized man, the most important condition is cleanliness. A dirty foot is necessarily an unsound foot. The cleanliness of men's feet can be insured by frequent cleansing, and careful drying after cleansing. Any moisture left between the toes, or elsewhere, will encourage putrefactive processes in any dirt, internal or external, that may accidentally be left in such positions.

After cleanliness comes the actual physical condition of the epidermis. In a man who has been in the habit of taking regular exercise, this will probably be hard and sufficiently resistant to withstand the ordinary friction of the march. In the case of peculiarly soft feet some hardening lotion—*e.g.*, formalin—may be used, or a solution of chromic acid, 10 per cent., or weaker if excoriations are present. In the case of men who suffer from hyperidrosis, more drastic measures are necessary. The patient must be detained in hospital for twenty-four hours. All the foot-gear must be sent for. The socks should be soaked for one hour in a solution of corrosive sublimate, 1 in 2,000, then well rinsed in hot water, and subsequently washed. The inside of the boot must be painted everywhere with a solution containing 1 ounce of salicylic acid in 10 ounces of spirits of wine. The feet are then carefully cleansed, and after drying painted over with the same solution. The chief attention should be paid to the red, sodden areas which are characteristic of the complaint. After this a clean pair of socks may be put on, or the foot covered with dry boracic

lint. The painting is repeated the following morning. The process is, in fact, one of thorough disinfection of the feet and their coverings.

The most important point is, however, to keep a close supervision over the feet of the men, and this is to a great extent a disciplinary measure. Repeated foot inspection must be made by the medical officer and company officers. In addition, men must be warned that they will be held responsible for reporting the slightest injury to their feet immediately at the conclusion of the march. The man who saves his sore feet till the next morning, and then reports sick, must be made to march, or have the seriousness of his negligence brought home to him in some other way. In the majority of cases the soldier who suffers from sore feet is as directly responsible for the accident as the cavalry soldier who rubs his horse's back, and should receive the same amount and kind of consideration. In this connection the ingenious invention of Dr. Coindreau may be mentioned. This officer applies a strap round the ankle and instep in a figure of eight, which immobilizes the foot inside the boot. The strap is pulled fairly tight, and fastened off by a buckle, which lies just in front of the external malleolus. In this manner the rubbed surface gets time to heal, and if the wound be in the meantime treated aseptically, recovery may be anticipated, even though the man continues marching. The care of the feet may seem a small thing, and to the medical officer ambitious of surgical or hygienic distinction appear rather below his personal or professional notice. There is, however, no duty more important, or the punctual performance of which will be more readily repaid by the sight of full ranks.

CHAPTER VI

FOOD AND DIETETICS

THE word "food" in its widest sense must be held to include all substances which man consumes with a view to nourishment, though it is more scientifically restricted to denote only those ultimate principles which supply either building material or fuel for the human machine. In the following section I will, where there is likely to be any ambiguity, use the expression "foodstuff" to connote the wider, and "true food" the more limited of the above meanings.

SELECTION OF FOODSTUFFS.—The foodstuffs which are used by man, whether civilized or savage, are not selected by him, primarily or knowingly, to meet any physiological requirements, except in so far as these are expressed by the natural longings and appetites. They are selected mainly on sensual or æsthetic grounds, the choice being tempered by the question of cost or procurability. Briefly, a healthy man eats what he likes and can obtain, with but little conscious thought, in the immense majority of cases, at least, as to whether it is suitable for the work he has to do or even consonant with the preservation of his health. But though it is true that men choose their food, not because it is good for them, but because they like it and can get it, still, it by no means necessarily follows that what they like is not at the same time the best for them. The foodstuffs that men eat are largely a matter of national tradition and custom—that is, of an unconscious adaptation of the individuals of a race to their surroundings. A tribe that persisted in consuming an unwholesome or unsuitable food must obviously either die out or deteriorate. It must, no doubt, have repeatedly happened during the course of history, that some particular race has been driven by

a more powerful enemy into a region where the best food was no longer cultivable or obtainable. Such a tribe must either die out or adapt itself to living on the inferior foodstuffs which are still available, and will thus perpetuate and accentuate its inferiority. It, in fact, will remain a poor race because its food is poor, and conversely its food will be poor because it is a poor race. On the other hand, it is hardly consonant with what we know of the process of evolution to suppose that the races which have for centuries dominated their neighbours have done so in spite of the fact that they persisted in living on unsuitable forms of food. In short, for a strong race national usage predicates a certain suitability in the dietary.

The student of dietetics who ignores these national and traditional prejudices will inevitably come to grief sooner or later when he finds that the hard facts of history run counter to his theories. So strong is the sentiment that attaches men to certain foodstuffs that it has on occasion happened that men have died of starvation, not because all food, but only the particular food to which they were habituated has failed. To ignore appetites so strong as these is the negation of science, and the cardinal error into which many so-called food reformers fall is trying to teach people to subsist on foodstuffs, which by national tradition—call it even national prejudice if you will—they are not in the habit of considering suitable articles of diet. The definition given by Dr. Johnson of oatmeal—namely, "the food of men in Scotland and of horses in England"—is an apt illustration of such a prejudice—one which, in spite of the counter-query, "Where do you find finer men or better horses?" persists in almost unabated strength amongst the working classes of the South to the present day. There is, in fact, ample physiological justification for yielding to—call it even pandering to, if you will—such national, social, and even personal predilections. Since the soldier leads a communal life, personal appetites have to be levelled up or down to a general regimental standard, but national and social habits are, and very rightly, allowed considerable weight in the arrangement of his messing.

Classification of Foodstuffs.—The enormous variety of foodstuffs available makes it necessary to adopt some

general form of classification to facilitate their discussion. That which I adopt is given in the following paragraph, and I will merely preface it by saying that I do not put it forward as being strictly scientific, but merely as a good working arrangement, which permits of all possible foodstuffs being included, and placed each under a heading which denotes its chief dietetic quality, though not its sole dietetic function.

All foodstuffs may be divided primarily into (1) those which are absorbed, and (2) those which are not absorbed, and these can again be subdivided as follows :

1. Foodstuffs which are absorbed—
   - (*a*) Those which help to build up tissues } the true
   - (*b*) Those which help to supply energy } foods.
   - (*c*) Those which assist in either of the above—stimulants and antiscorbutics.
   - (*d*) Those which hinder either of the above—poisons.

2. Foodstuffs which are not absorbed—
   - (*a*) Those which assist absorption—condiments.
   - (*b*) Those which do not assist absorption, but are mechanically beneficial on account of their bulk.
   - (*c*) Those which hinder absorption or cause injury—poisons.

As I have already premised, the above classification is not scientific, since any one food may fall under more than one of the above heads. Thus most of the true foods act both to build up the tissues and to supply energy, whilst any one of them, if taken to excess, or in individual cases even if taken in moderation, may act as a poison. Again, condiments are, as a matter fact, in most cases absorbed ; but their chief dietetic function does not depend on their absorption, and is, in fact, completed before that has taken place. They, too, may, if taken to excess, act as poisons, irrespective of the fact that they have previously had a beneficial effect, or not. Alcohol can supply energy, and therefore might be classed under the true foods. Its true dietetic value does not, however, lie in this direction, but in that of assisting the general processes of assimilation

and digestion, by the physical and mental excitement which it produces, and it is therefore rightly placed under the heading of "stimulants." Lastly, the complex animal and vegetable substances which form the staple of any diet contain ingredients which may be classed under almost any one of the different headings. Thus, for instance, a mutton chop consists mainly, as regards its solid constituents of protein material, a true tissue builder; it also contains fat, a true source of energy, whilst under certain conditions the former may supply energy and the latter build up, if necessary, tissue. In addition, there may exist some unabsorbable fascia or cartilage, which, if swallowed, will act to increase the mass of the fæces, and so assist peristalsis. Lastly, a spicule of bone may be ingested, and cause mechanical injury to the gastric mucous membrane, and thus act as a poison.

With these limitations and provisos, I have found the classification given above a good working arrangement for purposes of discussion. It will be convenient to consider the less important substances first, leaving the true foods for discussion last of all.

Condiments.—I have defined these as substances which are not absorbed, but which assist absorption. The chief condiments in common use are mustard, pepper, vinegar, various spices, and common salt, this last acting also as a true food. They act reflexly on the digestive secretions through the special nerves of taste, some also—*e.g.*, pepper, curry-powder, etc.—act on the gastric mucosa, producing free secretion as a result of direct irritation. It is a mistake to look upon condiments as luxuries. They are, in fact, necessary, especially in the case of civilized man, to effect satisfactory digestion and absorption, especially in the case of the less sapid vegetable foods. This action is not, however, confined to the actual substances which we know by the name of "condiments." Everything which tends to make the food attractive in appearance or odour, the surroundings in which it is consumed, luxurious table appointments, bright lights, pleasant companionship, all these tend to assist what Pavlov has termed the "psychic stimulus" to digestion. Most important of all is variety in diet. It may be true that hunger is the best sauce, but even hunger

cannot make a man relish the same food if indefinitely repeated, more especially if, however delightful it may be as an occasional article of diet, it is too cloying for persistent use. The old clause in servants' agreements in many parts of Scotland, protecting them against the issue of salmon on more than a limited number of days in the week, is an excellent instance of the effect of too frequent repetition. On active service it is often impossible to avoid this monotony of diet, sometimes for many days at a time. The corollary is that every effort should be made to take advantage of any opportunities for variety that may arise. In this connection the important digestive influence exerted by the soluble extractives of meat must be noted. These substances possess no inherent tissue-building power, but, as Pavlov has shown, if they are removed from meat by prolonged boiling and compression, the residue exercises but a feeble and purely mechanical stimulus on the gastric mucous membrane. The addition of Liebig's Extract to the sodden meat at once restores its activity. The individual extractives of meat, creatin, etc., do not appear to produce this effect by themselves ; the precise nature of the active substance or substances is therefore uncertain. The later researches of Thompson have furnished further proof of this fact, and there is evidence to prove that certain substances exist in the natural juices of the animal body which exert some direct stimulating effect on the gastric digestion. In the same way as pleasurable surroundings assist digestion, so do the reverse conditions inhibit and interfere with the process. The whole scheme of metabolism is so delicate, and its different parts so closely interwoven, that it would be difficult to say of any one outside influence that it might not produce some effect, for good or for evil, on this important mechanism.

Articles which are not absorbed, but are Beneficial on Account of their Bulk.—Little needs to be said under this heading. The most important member of this class is cellulose. Its presence is mechanically beneficial by exciting peristalsis, and when it is lacking, as in the absence of fresh vegetables, constipation is apt to result.

Poisons.—This expression is used purely in a dietetic sense. I do not refer under this heading to the various forms of

poisoning that result from putrefactive decomposition of meat, etc. The word in its dietetic sense refers only to substances which form parts of, or, indeed, themselves are, common foodstuffs. Of those which are not absorbed some may cause actual injury to the intestinal wall, such as spicules of bone, or the spines or stones of various plants and fruits. These are of little importance. The actual bulk of a foodstuff, which, as I have just stated, has up to a certain point a beneficial effect, may, after a certain point has been reached, exercise a poisonous action by impeding the absorption of other substances. The researches of McCay on this point, in connection with the diets of prisoners in Bengal, are most valuable. He has shown that with an excessive rice diet the absorption of protein is interfered with as a direct result of the bulk of the foodstuff in question, until with very large amounts the total protein absorbed is not only relatively, but actually, decreased by further additions to the dietary. Dealing with the British soldier, who does not, as a rule, consume large quantities of starchy foods, the point is not perhaps of great importance, but officers of native troops, whether Indian or African, should always keep this fact in mind when suggesting additions to a dietary. Besides the dietetic poisons which are not absorbed, we have to consider those which are absorbed. I do not here refer, as I have already said, to those poisons which are the results of decomposition of foodstuffs, nor to the accidental inclusion in a diet of pharmaceutical poisons, as, for instance, in the case of the substitution of aconitum ferox for horse-radish, or of poisonous fungi for the common edible mushroom. The poisons just mentioned are of comparatively rare occurrence, and therefore of comparatively slight importance. The substances which I include under this heading, and which are of real importance, are those which under ordinary circumstances, and in moderate amount, are true foods, condiments, or stimulants. I have already shown that the mere bulk of a food, which in moderation is advantageous, can, if pushed to excess, exercise a poisonous action by interfering with absorption. in the same way it is perfectly true that every member of the three classes just named may, if consumed to excess, act as a poison. Thus, excess of sugars and starches may lead

to dyspepsia and eventually glycosuria, excess of protein foods to albuminuria and uric acid poisoning, excess of fats to diarrhœa. Again, each and all of them may under certain conditions, or in certain persons, acts as poisons—that is, causes of illness—even when taken in comparative moderation. This is, of course, a mere commonplace. "One man's food is another man's poison." The point of these remarks lies in the fact that certain persons, best termed "food faddists," insist that the same article cannot at one time act as a food and at another as a poison, and argue that because it occasionally, in their experience, acts, or has acted, as the latter, it can under no circumstances act as the former. This seems to me a very dangerous fallacy, and it must always be remembered that the question whether any foodstuff shall act as a true food, stimulant, antiscorbutic, or condiment, on the one hand, or as a poison on the other, is merely a matter of quantity in all cases, and of idiosyncrasy in many.

Stimulants.—These are substances which, being absorbed, primarily assist absorption and metabolism, though one at least of them, and that the most important, alcohol, can and does act as a true food, in respect that its combustion in the body produces energy. Other stimulants are tea and coffee, and to a less extent chocolate or cocoa. The first two are not in themselves foods, though occasionally as actually consumed—that is, with milk and sugar—they may act as food adjuncts. Chocolate and cocoa, owing to the considerable portion of fat which they contain, are also, of course, true foods.

On the general question of stimulants and their necessity, it is only necessary to observe that they are universally used by civilized races, and their consumption must be taken therefore as the response to a want felt, if not by all men, at least by all races higher in the scale than the lowest savages. If not necessary in the sense that man cannot live without them, they are at least so in the sense that he will not live without them if he can by any possibility procure them. As to the result of consuming stimulants, the general experience is that in moderation they do no harm, whilst at the same time, as a result of the pleasurable mental or psychic effect produced, they undoubtedly promote comfort,

and, when taken reasonably with meals, assist digestion and metabolism. In excess they may act as poisons, and in this case more than any other idiosyncrasy plays a large part. The degree of concentration in which they are ingested is also of importance, and this is as true of tea and coffee as of alcoholic fluids, whilst tea, if badly "made," may, owing to the tannin present, act as an immediate cause of dyspepsia. So far what I have written is equally true of all stimulants, and is probably sufficient on this point. The question of the consumption of alcohol stands on a somewhat different footing to that of other stimulants, and this matter therefore demands somewhat more lengthy treatment.

Alcohol.—The difference between alcohol and other stimulants consists in the fact that, quite apart from its effect on the body as a stimulant, it also exercises an important moral and mental influence. Consumed in excess it cannot possibly have any defenders at the present day, though it may be noted that a little over 100 years ago an eminent Scotch judge declined to accept the fact of drunkenness as a plea, in extenuation of punishment for crimes committed under the influence of alcohol, on the grounds that its effect should be such as to exalt the moral tone of those indulging in it. Other days, other customs. It is safe to lay down as an axiom that the consumption of alcohol in excess is bad in every way, physically, mentally, and morally. The discussion only turns on the point as to what constitutes excess, and whether its consumption in moderation is pernicious or not. There are many honest men who sincerely believe that indulgence in alcoholic liquors in any form whatsoever, and in any quantities, however small, is hygienically and morally wrong, and that, in the words of Sir Victor Horsley ("Alcohol and the Human Body," p. 353), "what is commonly described as moderate drinking has a most injurious influence on health and life, and that the best practice, both in the interests of health and morality, consists in the avoidance of all alcoholic drinks as beverages." I need hardly say that this is a moderately worded statement when compared with those of many supporters of this view. On the other hand, there are as many, if not more, equally honest men, who sincerely believe that they can lead the lives of useful citizens, none the worse but even

the better, for the fact that they, as a matter of rule and practice, do habitually indulge in moderate drinking.

The subject is of such enormous importance, from a hygienic point of view, especially in connection with the population dealt with in military sanitation, that any teacher of that subject is bound to face it, and to point out clearly the position he adopts in regard to it. In the first place, and to clear the ground, it is necessary to define what moderate consumption of alcohol really means. To begin with, no one ever does, as a matter of fact, drink "alcohol." The strongest spirits usually consumed consist of about half and half of alcohol and water. Again, no man who habitually or even frequently consumed raw spirits could be described as a moderate drinker. Therefore, in the second place, the average man takes his alcohol diluted with from about 15 to 95 parts of water, in proportion as he drinks the ordinary whisky-and-soda, or some of the lighter wines or beers. In addition to the water, he adds sugars, colouring matters, bitters, and other flavouring matters to the already diluted alcohol. Again, a man who drinks even this diluted and flavoured alcohol to any great extent on an empty stomach could not well be called a moderate drinker. Therefore, in the third place, this alcohol already highly diluted and flavoured, is mixed in the stomach in the enormous majority of cases with solid food of some nature or other. Lastly, the term "moderate drinker" would not in general be applied to a man who drank spirits, beer, or wine at his morning meal, or, indeed, who indulged in a glass of the same "in the middle of the morning." Therefore, in the fourth place, this diluted, flavoured alcohol is not consumed before a good half of the day's work is presumably done. I think that the majority of my readers would recognize as a moderate drinker a man who drank a moderate amount of wine, or spirits and water, or beer at his meals, with perhaps a whisky-and-soda after his daily game of polo, or what not, and another as a "night-cap" before going to bed, and who was not in the habit of drinking anything at all of this nature before the midday meal.

Accepting the above definition, is there any evidence that men who follow such a course of life are worse men physically and morally than the men who abstain alto-

gether ? I think not. The description just given would apply to the great majority of educated, active-bodied men in the British Isles, and, in fact, throughout Europe. Sir Victor Horsley produces statistics to show the great difference in mortality between total abstainers and moderate drinkers, and, indeed, these are the strongest arguments he adduces. But I cannot see that there is any assurance that the numbers returned as moderate drinkers do not in fact include a great many people who had no claim to that title. It is but rarely that a man will openly acknowledge to being a drunkard, and I therefore pay the less attention to the statistics of this kind. I will venture an attempt to arrive at the truth in another manner. The proportion of teetotallers amongst the officers of the army is comparatively small ; the immense majority are moderate drinkers—in other words, they habitually consume about the amount of alcohol which I have laid down above as being the average standard of that class, and would look on any marked excess above that amount as depriving the individual concerned of the right to be called a " moderate drinker." Probably 75 per cent. consume less than half that amount. Nevertheless, in spite of the fact that, though the majority of these men indulge in a habit which, according to Sir Victor Horsley, should have " a most injurious influence on health and life," the class to which they belong will compare favourably as regards health, activity, and longevity, with any other in the country, and that in spite of the fact that many of them are handicapped by exposure to trying climates.

Again, it is often stated that the health of the race is affected by even moderate drinking. Quite apart from the fact that this statement is unsupported by any statistical evidence, it must be remembered that the present living members of the Teutonic and Scandinavian races, which for so many centuries have played a leading, if not the leading, part in the history of the world, are descended from a stock peculiarly addicted to the free consumption of alcohol, and that, speaking for our own race, the British, 100 years ago drunkenness was rife from the Cabinet Minister to the coal-heaver. Whether the race be degenerate at the present day or not is a matter of opinion, which in the absence of

accurate anthropological measurements, is incapable of proof. It would be rash to apply that term to Nelson's sailors, or the men who followed Wellington, and it seems improbable that what had not been effected by the drunkenness of the previous 1,500 years should have been caused by the moderate drinking of the comparatively temperate century that has elapsed since then. I wish it to be distinctly understood that I am speaking from the point of view of the student of hygiene, not from that of the teacher of morality. The case for temperance is so overpoweringly strong that it is a pity that its advocates should weaken it by making statements which are contrary to the ordinary experience of mankind. Such statements merely discredit the cause which we all have at heart, those who may be called "moderate drinkers" just as strongly as those who are actually total abstainers.

Strictly speaking, alcohol must be looked on as a food, since its combustion in the body produces a certain amount of heat, and thus saves for the use of the body an isodynamic quantity of fat or carbohydrate. In actual practice, however, it cannot be used as a food, since in quantities sufficient to produce any substantial supply of energy the effect on the central nervous system would be so great as completely to neutralize any good effects so produced. It occupies, in fact, much the same position *qua* food in the human body as it does *qua* fuel outside. A spirit-lamp is an extremely convenient lamp if it is required to boil a kettle in a hurry, but an extremely bad one if it is required to light or heat a room. Alcohol is a bad food if it is required to supply energy for a forced march, but an extremely good one when it is necessary to spur a man to make himself comfortable for the night, instead of collapsing into an unrefreshing sleep, unsheltered or unfed.

The proper function of alcohol, then, is to assist absorption and metabolism, and in practice in the Service its issue is limited to occasions when, owing to fatigue or exposure, these functions are apt to be interfered with or inhibited, as, for instance, when, owing to the discomfort engendered by inclement weather, the men are not likely to make the best of their evening meal. It should never be issued on occasions when men are expected to make a march, or to

men likely to be exposed either to severe cold or the other extreme of intense heat. It should be given at the conclusion, never before or in the middle of work. Owing partly to its local irritant action on the gastric mucosa, and partly also to its actual combustion, alcohol produces a sensation of warmth, which, in as far as it is due to the former reaction, is, of course, fictitious. The heat actually produced is dissipated by a dilatation of the superficial capillaries, but the rapidity with which this takes place is largely dependent on the amount of clothing worn. The man who comes into camp cold, and drinks his "tot" of rum between the blankets, close to a fire, undoubtedly retains sufficient heat in his body as the result of the combustion of the alcohol to be of serious value. The same man drinking his rum before standing as sentry in an exposed position, on a cold night, will probably suffer a loss of heat greater than the amount actually to be credited to the combustion of the spirit.

Antiscorbutics.—The cause of scurvy is as yet unknown, and therefore it is difficult to enumerate exactly the substances which act as antiscorbutics. Lime-juice and fresh vegetables are the foodstuffs which are usually recognized as fulfilling this rôle, but there have been cases, though few, in which the disease has occurred, in spite of the presence of these articles in the dietary. Still, the experience of the Royal Navy and mercantile marine is fairly conclusive, that in the enormous majority of cases the absence of these is the cause and their addition to the dietary the best remedy for scurvy. It is possible that under the name of "scurvy," which is, in reality, more of the nature of a symptom-complex than a true disease entity, we are in reality including more than one pathological condition. Certain it is that we cannot find any one cause that will absolutely cover all the various outbreaks which have passed under this appellation. There is, quite apart from the purely dietetic causation, a strong psychic element occasionally present, as in the case of prisoners of war, who are particularly subject to this complaint. A monotonous diet undoubtedly appears to conduce to the production of scorbutic symptoms, and, indeed, if there can be said to be any one factor common to all outbreaks, then monotony of diet is probably the condition in question.

Knowing, as we do, the effect of psychic influences on the digestion, it is quite conceivable that one effect of a persistently monotonous diet may be to interfere with one or more of the delicate links in the long chain of metabolism. The effects of such a breach of continuity may be the same, even though the breach may not always effect the same links on all occasions. In any case, a complete change of diet, and, if possible, of scene, is necessary if we wish to prevent or put a stop to an outbreak of scurvy. A microbial origin has been suggested, but, though in the later stages, when ulceration has taken place, of the gums particularly, a secondary condition, due to infection by micro-organisms, may complicate the original disease, the balance of evidence still seems in favour of a purely dietetic origin.

The True Foods.—We now come to a discussion of those substances which either go to build up the tissues or supply energy to the body, or perform both these functions. These alone are entitled to the appellation of "true foods." Conversely, all things whatsoever that can fulfil the above purposes in the human body are foods. They may be bad or unsuitable foods at all times, or only under certain conditions, as when taken to excess, or in a disordered condition of the digestive system, or, again, only to certain individuals. In the same way any matter that will burn in a fire is fuel, though it may, under certain circumstances be a bad, or unsuitable, or even a dangerous, fuel. The choice of a food out of all the long list available is a matter to be decided by the individual under the peculiar circumstances in which he finds himself.

The true foods are classified as follows :

1. Inorganic.
   - Water.
   - Salts.
2. Organic.
   - (*a*) Nitrogenous : Protein.
   - (*b*) Non-nitrogenous : Fats.
     Carbohydrates.

Water.—Water is not, as a rule, looked on as a food, but it is, in reality, the most important of all foods, and may,

in fact, be looked on as the only indispensable *daily* food. Its function is to build up the tissues, and since two-thirds, roughly, of the human body consists of water, its importance as a tissue-builder is at once obvious. In addition, its presence is essential to the performance of the ordinary chemical reactions of hydrolysis and oxidation, which constitute such a large part of the process which we term "metabolism," and also to the efficient carrying out of the automatic heat-regulating mechanism of the body. The water necessary for the above purposes is furnished in the form of a fluid, or as a constituent part of the ordinary solid foodstuffs, or, again, to a slight extent by the oxidation of hydrogen in the body. The amount necessary depends largely on the work done by the individual, the surroundings under which he lives, and the nature of his food. The smaller the amount of water contained in the solid foodstuffs supplied, the greater is the amount that must be furnished in one or other of the ways just mentioned, and principally, of course, in the form of drinking-water. This fact should always be kept in mind when soldiers are being fed on concentrated foods. It is possible, of course, to increase very greatly the portability of meat by driving off say, 90 per cent. of the water which it contains, and if this is done with care, neither the digestibility, palatability, nor energy value of the food need be interfered with. Under certain conditions such a degree of concentration might solve some difficult problem of supply. But it must be remembered that the water which has been removed to make the food portable must be supplied in some other form if the soldier is to be properly nourished. We carry concentrated food presumably because it is not available in its natural form in the country through which we are passing. As long as water is available in that country, we are justified in saving transport by carrying only the solid constituents of the meat, but only on condition that water is available. In the last resort, and if a choice had to be made, it would be necessary to leave the solid food and carry the water, not with a view to reducing the discomfort produced by thirst, but to escape the certain death which would result, and very rapidly, from water-starvation, of which the sensation we term "thirst" is merely a sign. The expendi-

ture of water during work is directly proportional to the work done and the necessity that arises for regulation of the body temperature by evaporation. It will, therefore, obviously be increased by marching in a hot climate, the very conditions under which scarcity of drinking-water may be anticipated. It must be remembered that a healthy man carries a considerable reserve of fuel in his body to supply energy in the absence of fresh supplies of food, and can subsist, in spite of starvation in this direction, for a period to be measured by weeks. He carries, on the other hand, a very small reserve of water, and his term of endurance, supposing this supply to be cut off, is one which may be stated in days, or, if the work be severe, in hours only. This subject has already been referred to when discussing the supply of water on the march.

Salts.—The body contains about 5 per cent. of its weight of mineral matter. The most important of these salts are the chlorides of sodium and calcium, the carbonates of sodium and calcium, and the phosphates of potassium, calcium, and magnesium. Iron is also present in the hæmoglobin, and though the total amount is small, its presence is essential for existence. The only salt that is taken as a foodstuff is chloride of sodium. All the others are provided in the form of by-products, as it were, in a well-regulated mixed diet. If an animal be fed on a food from which all mineral salts have been excluded, it begins to show nervous deterioration in about three weeks, and succumbs in from four to five weeks. The total amount of any one salt required in any one day is, of course, extremely small, when compared with the more bulky organic foodstuffs. This fact is of considerable importance. The amount being so small, its absence is easily overlooked, and many obscure cases of malnutrition, or that condition which is generically termed "scurvy," are probably due to the prolonged omission from the diet of some one salt, though not in all cases of the same salt. Such a condition of affairs is naturally not unlikely to occur when men are placed on a monotonous and restricted diet. The addition of chloride of sodium to the diet is not an absolute necessity, since it may be supplied as a constituent of some of the flesh foods. Carnivorous animals, as is well known, do not seek for

" salt-licks " in the same manner as those belonging to the herbivorous genera. Still, in the case of civilized men consuming a normal mixed diet such an addition is demanded, and those who live largely on vegetable foods need an even larger allowance. An excess of salt has been shown by McCay to have a positively deleterious effect, and the researches of Marey and others show that a " water-logged " condition of the tissues may be produced, which is apt to aggravate any inflammatory process and lower the powers of resistance of the tissues in the case of injury. The well-known fact that slight accidents are apt to lead, in the case of scorbutic men fed on a salt-meat diet, to serious tissue-destruction is probably not unconnected with this tendency. In such cases the general scorbutic condition may be due to a defect of some particular salt in the dietary—*e.g.*, phosphates—whilst the local manifestations are due to the excess of some other salts—the chloride of sodium and nitrate of potassium.

Organic Foods.—We now come to the consideration of the true foods which are derived from the animal and vegetable kingdoms. Water and salts are, it is true, to a certain extent (in the case of the salts to a considerable extent), derived from these kingdoms ; but since they are partly and—as regards water, at least—most conspicuously ingested as such, I have separated them from the organic foods.

The organic foods are divided into nitrogenous and non-nitrogenous.

The nitrogenous foods are derived from both the animal and vegetable kingdoms, though, as a rule, to a greater extent from the former than the latter. These foods are absolutely essential to life, since they alone supply the indispensable nitrogen. Life can, in fact, be supported on protein (with the addition of water and salts alone), as is the case with carnivorous animals, and with a few savage tribes. As a rule, and invariably in civilized man, however, this is not the case, fats and carbohydrates being also used.

The chemical constitution of proteins is extremely complex, and their molecular arrangement even more complex than their chemical composition.

Their fate in the body may shortly be sketched as follows :

After ingestion, they pass unaltered to the stomach, and are there at once acted on by the gastric juice and pepsin secreted by the gastric mucosa in response to the reflex stimulation conveyed from the mouth, but largely, if not principally, as a result of the psychic stimuli already referred to. The digestive action does not begin at once, but only when the alkaline reaction of the food, due to the ptyalin of the saliva, has been overcome. The result of this gastric digestion is the production of acid albumins, proteoses, and, finally, peptones. For this transformation to occur it is absolutely necessary that both pepsin and free hydrochloric acid should be present. Under ordinary circumstances the transformation of proteins does not go beyond the stage of proteoses and peptones in the stomach, though, if the passage of the food be artificially delayed, a further breaking up of these still complex bodies can occur. Normally, however, the proteins, now in the form of proteoses and peptones, and some, indeed, still unaltered, pass into the duodenum. Here they come under the influence of the ferments contained in the pancreatic juice, bile, and succus entericus. The reaction of the contents of the duodenum is alkaline, which at once puts a stop to any further action of the pepsin, but allows the even stronger ferment trypsin full play. Trypsin, which is the result of an interaction between the trypsinogen of the pancreatic juice and the entero-kinase of the succus entericus, attacks not only the proteoses and peptones coming from the stomach, but also the still unaltered proteins that have escaped the action of the gastric juice, and reduces all these to the stage of amino-acids—bodies that are still of a complex nature, but far less so than the original proteins from which they descend. There is evidence to show that this action of trypsin is more complete when it meets with already altered proteins than with those which have passed through the stomach unattacked. Amongst these amino-acids may be mentioned glycin (or amino-acetic acid), leucin, tryosin, and tryptophane. In addition to trypsin, however, there is present in the succus entericus a ferment named "erepsin," which also acts strongly on the peptones, but is unable to attack native proteins, with the exception of casein, which is feebly digested, while it acts slowly or

not at all on the first-formed or primary albumoses (Pavlov). This ferment is present not only in the succus entericus, but is widely spread in different tissues, and, amongst others, in the gastric mucous membrane. It is probable that in this last position it acts on any proteoses and peptones that are absorbed from that organ, since these substances are never present in the blood. The ultimate absorption of proteins takes place in the form of amino-acids, or even of simpler compounds.

The protein tissues of the body must obviously be built up from the protein tissues of the food, but the process is not one merely of resynthesis, but of selection plus rearrangement, followed by the formation of new synthetic compounds. The generally accepted view is that the body appropriates to its own uses such of the different end products of protein digestion as are suitable to its needs, rejecting those of which it is unable to make use. These last are split up into a carbohydrate and a urea moiety, the former of which is stored up in the form of glycogen, the latter excreted as urea by the kidneys. The actual process is not, perhaps, or even probably, so simple as this. It is quite possible that both the glycogen and the urea are built up from débris of protein molecules in an extreme state of disintegration. It is unnecessary here to go into these abstruse points of metabolism. What it is most important for the student of dietetics to remember is that, regarded as a tissue-building food, protein is of value, not merely *qua* protein, but *qua* useful protein. The whole question of the amount of protein food that should be consumed hinges on this point, which will be referred to later, when discussing that question.

The non-nitrogenous foods include the fats and carbohydrates.

The fats are, chemically considered, glycerine esters of the fatty acids, and contain carbon, hydrogen, and oxygen. Considered in the light of fuel, it is important to remember that the oxygen present in the molecule is not sufficient to satisfy the hydrogen which the latter contains. The energy value does not depend, therefore, as in the case of the carbohydrates, purely on the carbon of the molecule. The fats are practically unaffected until they reach the

small intestine. Here they are emulsified by the action of the bile, and then broken up by the action of the steapsin of the pancreatic juice into fatty acids and glycerine. These are again resynthesized in the intestinal wall, and absorbed by the lymph ducts in the form of the fat originally ingested. This fat is then stored in the body as depot fat, and is available as a store of energy or warmth in emergency —*e.g.*, in starvation.

There is a certain amount of fat in the body which forms part of the active tissues, and this is peculiar to the body. It is probably made up indifferently from proteins, fats, or carbohydrates. This fat does not entirely disappear, even in extreme starvation. In respect of this "tissue fat," the fat of the diet may be looked on as a tissue builder. The main use of fat, however, is to form a reserve of energy.

The carbohydrates are, considered chemically, aldehyde, or ketone derivatives of the polyatomic alcohols, and contain carbon, hydrogen, and oxygen, the last two being in the proportions necessary for the formation of water. The fuel value of the carbohydrates depends, therefore, solely on the carbon present, and is thus inferior to that of the fats. The carbohydrates may be divided into the mono-, di-, and poly-saccharides. The two former classes include the ordinary sugars (grape-sugar, cane-sugar, milk-sugar, etc.), the third class the gums and starches. The starches are attacked by the saliva and converted into maltose and, to a slight extent, into dextrose; but this action does not, as a rule, progress very far, since it is checked as soon as the food reaches the stomach, or as soon, rather, as the reaction is altered from alkaline to acid by the action of the gastric juice. It is important to note that the starches are the only foods which are digested in the act of chewing. Proteins and fats are merely mechanically disintegrated in the process. Too prolonged a mastication of protein food would probably exercise an adverse influence on the subsequent digestion of these matters in the stomach, owing to the excessive flow of alkaline saliva thus produced. Prolonged chewing may, owing to the laborious nature of the process, be useful in the case of people who are prone to overeating; otherwise, except in the case of the carbo-

hydrates, there does not seem to be much physiological justification for the practice. The chief digestion of the sugars and starches takes place in the small intestine, as a result of the action of amylolytic ferments contained in the pancreatic juice and the succus entericus. The former converts the polysaccharide, starch, into the disaccharide, maltose, but, as in the case of the saliva, does not carry the action further to any great extent. The succus entericus, on the other hand, attacks starches feebly, but converts maltose into dextrose. Eventually all the carbohydrates ingested are reduced to the dextrose or monosaccharide condition, and absorbed in that form. This is conveyed by the portal blood-stream to the liver, and there again reconverted into glycogen, one of the polysaccharides. This substance, which is the great store of energy in the body, is distributed to the working parts in the form of dextrose by the general circulation. Glycogen can be formed from protein, as already described, and also (almost certainly) from fat. On the other hand, carbohydrates can be converted into fat if necessary.

Surveying the whole question of digestion and absorption, it is important to note one or two points. The chief digestive organ is the upper part of the small intestine. Here all of the three organic foods are digested. The stomach acts mainly as a reservoir where the diet components are mixed and, as it were, standardized, certain small portions being ejected into the small intestine as required. A certain amount of absorption of dextrose or amino-acids may, it is true, take place here, but this is not large in amount. At the other end of the chain the large intestine again acts as a regulator, permitting of the accumulation and periodic discharge of food waste. The second point is that all absorption is the result of a process of splitting up of foodstuffs into simpler molecular arrangements. Under ordinary circumstances this process follows certain fairly defined lines, which I have endeavoured to sketch above. There is no reason to suppose that ordinarily the body breaks down the different food molecules to any greater extent than is absolutely necessary—in fact, such a theory would run counter to the economical principles on which the organism works. To what exact degree it is necessary that

food protein should be broken down before it can be re-synthetized into body protein depends to a certain extent probably, on the one hand, on the nature of the former, and the actual emergent demands of the body for some particular form of protein on the other. It is reasonable to suppose that, under certain conditions, the chain of metabolism may be much shorter and the process of disintegration much less severe than in others. It is, in my opinion, not possible for us to lay down any definite limits to the powers possessed in case of emergency by the body of breaking down complex molecules and building up entirely new rearrangements of their ultimate chemical constituents. If necessary, it will go far to attain its object, but, however roundabout the path may seem, it will in all cases be the shortest feasible under the actual conditions.

Quantity of Food Needed.—The total quantity of food needed must obviously depend on the demands of the body for fuel and building material. This quantity is usually estimated in terms of energy units — that is, of fuel. The unit in general use in the discussion of dietetics is the large "Calorie." This is equivalent to the amount of heat necessary to raise 1 kilogramme of water at 20° C. through 1° C. The number of units expended in the twenty-four hours depends, of course, on the activity or otherwise of the individual. Zuntz gives 3,000 Calories as the estimated expenditure of a soldier's day in barracks, and this corresponds fairly closely with the general allowance for a life of moderate exercise.

This amount of energy must obviously be supplied from the proteins, fats, and carbohydrates of the diet, and these various principles furnish this energy in the following net amounts—viz. :

1 gramme protein furnishes 4·1 Calories.
1 gramme carbohydrate furnishes 4·1 Calories.
1 gramme fat furnishes 9·3 Calories.

Obviously, there is one fallacy in the above method of estimation, since it makes no allowance for tissue building, and, in consequence, it is first necessary to ascertain the amount of protein needed under this heading. If a man be subjected to absolute starvation, it is found that he excretes

an amount of nitrogen which represents the metabolism of rather more than 1 gramme of protein per kilogramme of body weight. Thus, in a seven days' starvation experiment, conducted by Benedict, the subject, weighing 62 kilogrammes, metabolized on the different days 73·4, 74·7, 78·1, 69·8, 65·2, 64·4, and 60·8 grammes of protein respectively. If, however, to a man thus starving an exactly similar amount of protein food be given (all non-nitrogenous food being withheld), it is found that, instead of the intake and output being balanced, the former is unable to keep pace with the latter, and a certain amount of nitrogenous starvation persists. If the quantity of protein food be now slowly increased, it will be found that the output still rises, but less slowly, until a point is reached, which may be placed roughly at 2 grammes per kilogramme of body weight, at which the excretion and ingestion of nitrogen exactly balance each other. This point may be called "the lower limit of nitrogenous equilibrium." Any increase in the protein of the food above that amount will result in an increased excretion of urea, and the condition of equilibrium will be maintained until a very high level of intake indeed is reached, which may be called "the upper level of nitrogenous equilibrium." Above this point the excretory organs will be unable to cope with the intake, and accumulation of nitrogenous material in the body will result. Briefly, it may be said, then, that within extremely wide limits the body is capable of maintaining its nitrogenous tissues—in other words, its general framework—at a constant weight, irrespective of the amount of nitrogenous food supplied.

In an experiment of the above nature the protein food has to furnish not only sufficient material to repair the ordinary daily wear and tear of human existence, but also enough to supply fuel for the production of the energy demanded by the work, internal and external, performed by the individual. Clearly, then, if this latter can be supplied from any other source, it should be possible to force down "the lower level of nitrogenous equilibrium" to an extent corresponding closely to the amount of protein food which had on the restricted diet been hypothecated for the supply of energy. In practice, as we know, no civilized men, and but

few savages, live on a purely nitrogenous diet, and the process of metabolism on the usual mixed diet may be briefly stated as follows : All the protein which is ingested must be disposed of if nitrogenous equilibrium is to be maintained. So much of what is suitable as is needed to replace inevitable waste is built into the tissues, and that which is not needed, or is unsuitable, is broken up, as already described, the urea moiety being excreted, and the carbohydrate moiety stored for use. Any balance of energy that is required is furnished by the fats and carbohydrates of the diet. *Prima facie*, the above process is wasteful, both in the physiological and the monetary sense of the word. It is wasteful physiologically because the whole of the protein molecule is not utilized. The excreted urea contains a certain amount of unoxidized carbon and hydrogen, and the loss on this account of the potential energy present in the protein molecule may be placed at nearly 30 per cent. On the other hand, the whole of the energy present in every molecule of fat or carbohydrate absorbed is transformed to heat or work in the body. From the physiological point of view, therefore, it is much more economical to furnish the necessary energy from fat or carbohydrate than from protein. It is wasteful in the monetary sense, since the protein-furnishing foods are, on the whole, more expensive than those which contain only the non-nitrogenous principles. A strong case, therefore, exists for those who hold that the amount of protein ingested should be just sufficient to replace the daily wear and tear of nitrogenous tissue, the purely energy demands being met by fats and carbohydrates only. The most reliable and extensive laboratory experiments on this point are those of Professor Chittenden of Yale. He has shown that health and strength can be maintained by various individuals (soldiers, students, and athletes) on a diet containing on an average only 0·150 gramme of nitrogen (corresponding to 0·94 gramme of protein) per kilogramme of body weight. The facts as recorded by Chittenden are indisputable, and he seems to hold a fairly strong position in urging, as he does, that a rational diet for a civilized man should be based on an allowance of protein food no higher than that stated above. He is, I think, on less sure ground, since he adduces no

direct experimental proof of his assertion, when he states that " any excess of protein food over and above what the tissue cells really need for their daily repair " entails " unnecessary labour on the part of the organism, and at the same time " exposes " the tissues and organs to the possible deleterious action of this uncalled-for excess of nitrogenous waste products prior to their elimination from the body." Such a statement presupposes a lack of elasticity in the physiological mechanism which is not supported by experience. Still, quite apart from this possibly pathological aspect of the question, the purely physiological arguments adduced by Professor Chittenden in support of his views are undoubtedly very strong.

On the other hand, if we apply the test of history, we find that the leading nations of Europe, and amongst them more particularly the governing classes, have, for as long a period as we have any record, habitually consumed at least twice as much protein food as Professor Chittenden recommends, whenever they have been able to procure it ; and, moreover, that a very fair test of the prosperity of any particular class might be made by observing the amount of protein food, more especially animal food, consumed by its members. There is no proof, as far as I can see, that these races have in any way suffered in consequence of this indulgence. They have led the other nations of the world for many centuries, and amongst them that nation which has always been notorious for its high consumption of protein has been by no means backward in the race. The struggle for existence between the various European peoples has been so keen during the last 500 years that any race which wilfully handicapped itself by persistent disobedience to some physiological law must have fallen back in the competition. If Professor Chittenden's theories are sound, then the English nation has undoubtedly so handicapped itself in comparison with the other nations of Europe. It will, I think, hardly be seriously urged that Great Britain is seriously behind the continental nations, or that the people of Europe and North America are far behind the other peoples of the world, be the test what it may.

So far the historical argument only goes to prove that a

successful national life is not inconsistent with a high protein consumption. It does not prove that an equal amount of success might not have been achieved on a smaller allowance of this food principle. On this point also, however, history can throw some light. In the Bengali race we find a people who, for as many years as we have record, have lived on a diet which the researches of McCay show to be, as regards the quantity of protein present, closely in accord with the principles of Professor Chittenden. As regards his physical development, Captain McCay shows clearly that the Bengali is in this respect of an inferior type, being 25 per cent. lighter than the average European, with a smaller chest measurement, though much the same stature. The blood of the Bengali, containing about 25 per cent. less hæmoglobin than that of the European, flows at 25 per cent. less pressure. As compared with Anglo-Indian and Eurasian students, the Bengali youth shows no progress in development during the years sixteen to twenty, though the several classes live under much the same surroundings, differing chiefly in the fact that the members of the two first-mentioned classes consume about 0·19 gramme of nitrogen per kilo of body weight as compared with the 0·11 gramme of the Bengali. As regards physical endurance and activity, the Bengali labourer is enormously inferior to the European. Insurance offices in Calcutta rate all Bengali lives as being five years worse than European lives ; one large office will accept the policies of well-educated Bengalis of the higher castes only, and even then not beyond the age of thirty-five to thirty-eight years. A very strict medical examination is made, a slight excess measurement round the waist being sufficient to insure rejection. At the same time, renal disease is twice as prevalent amongst native patients in the Medical College, Calcutta, as amongst European patients, though scarlet fever is unknown in India. As regards the position held by the Bengali race amongst the other inhabitants of the peninsula, history shows us that they have been consistently for centuries the hewers of wood and drawers of water for their more powerful northern neighbours. They are conspicuous amongst all the peoples of India for the fact that no member of the race has ever served in the ranks of our native regiments.

The fighting races of India have been those whose food has consisted of the grains richer in protein—*e.g.*, wheat—and whose diet has in most cases included a certain amount of meat.

Lastly, we have the evidence of men who have changed from the low protein diet of their homes to the higher rate of consumption prevalent in some land to which they have emigrated. On this point the evidence of Dr. Hutchinson, of New York, is very interesting. He states that Japanese labourers coming to the United States increase their working powers, and their corresponding wages, by 50 per cent. when they turn to a full meat diet, and that nearly the same improvement has been noticed in the case of West Indian negroes, employed on the Panama Canal, when placed on Northern Army rations.

The explanation of the apparent contradiction between the results of experience and experiment lies in the fact that what is needed is not any actual amount of protein as such, but a definite amount of suitable protein. The question is, in fact, one not of quantity, but of quality. A man must eat enough suitable protein to replace his daily wear and tear. To enable him to procure this suitable protein, it may be necessary for him to consume a considerable bulk of unsuitable protein, the extent to which he is driven in this direction depending entirely on the nature of the foodstuff most conveniently available, and the extent to which the proteins it contains correspond to the actual needs of the body at the time. In Professor Chittenden's experiments the subjects were carefully selected. Especially amongst the soldiers, "many were found unsuited for various reasons, and were quickly exchanged for others better adapted for the successful carrying out of the experiment. Several quickly deserted, not relishing the restrictions under which they were compelled to live." One man was rejected as physically unsuited (no explanation given), another as physically unsuited on account of a high grade of myopia, another as mentally and morally unsuited. Their lives were carefully ordered hour by hour, and "every precaution to preserve the health and good spirits of the men was taken." The food had to be carefully selected, since "it was necessary in prescribing the daily diet to see that

the quantity of the food was such as to completely satisfy the appetite. This necessitated the use of a considerable bulky food of low fuel and low nitrogen value." In such a process of selection there must inevitably have been some notice taken of quality. Unsuitable or obviously indigestible food would certainly have been rejected. Naturally also the men did not suffer from any particular anxiety as to where the next meal was to come from, or how much they could afford to spend on it. I must decline to accept evidence so procured as a safe guide in laying down a standard dietary even for the well-paid artisan or busy professional man, whose lives are less carefully ordered for them, and whose food is less carefully selected ; much less, then, for men like the agricultural labourer or the country doctor, who have to take their chance of wind and weather, and whose meals and rest have to fit in as best they may among the other claims of a hard-worked life ; even less, then, for the soldier on service, exposed not only to the elements, but also to the intense nervous and physical strain of war, whose food is badly cooked, of such quality and quantity as luck may allow, and to whom a good night's rest is often an impossibility. A man's food must be fitted to the life he leads. As long as he leads a laboratory life he can live on laboratory fare, and Professor Chittenden's rules are then possibly the best he can follow. As long, however, as he leads the rough-and-tumble life of the average wage-earning man, he will find the experience of his forefathers, as embodied in the dietetic practices of the successful members of his race, a safer guide than the experiments of the physiological chemist.

I cannot do better than close this section with a quotation from Mr. Benedict, which runs as follows : "Dietary studies all over the world show that in communities where productive power, enterprise, and civilization are at their highest, man has instinctively and independently selected liberal rather than small quantities of protein." For the above reasons I consider that the amount of protein in the diet of a man doing moderate work should be somewhere about 2 grammes per kilo of body weight. For a 10-stone man this will amount to 126 grammes. Since it is more convenient to deal with round numbers, I will,

for the purpose of the present discussion, fix it at 120 grammes.

The energy value of this amount of protein is 492 Calories, and the residue of, say, 2,500 Calories must be made up accordingly by means of fats and carbohydrates. It is generally held that these can replace each other to a very great extent so long as neither is entirely absent from the diet, and in practice the relative proportions of these two substances are regulated very largely by pecuniary considerations. The richer classes eat more fats, and the poorer more carbohydrates. Strictly speaking, however, it is probable that we cannot calculate on the basis of energy value only. It is not, in other words, correct to replace fats by carbohydrates, or *vice versa*, on a purely isodynamic basis of calculation ; the proper ground of comparison is their power of forming glycogen, and as this is more readily supplied by carbohydrates than by fats, a certain balance must be held to exist in favour of the former. The ratio of fats to carbohydrates observed in actual dietaries ranges between very wide limits, as shown in the following list (the figures in brackets denote the total potential energy of each diet) :

Ordinary prisoners, Scotland, light work ..	(3,115) 1 to 15
" Hard-worked " weaver, England ..	(3,569) 1 to 14
" Fully-fed " tailor, England	(3,053) 1 to 13
" Well-paid " mechanic, Munich	(3,085) 1 to 9
Carpenter, Munich	(3,194) 1 to 7
Painter, Leipsic	(2,500) 1 to 5
Physician, Munich	(2,762) 1 to 3
Lawyer, Munich	(2,401) 1 to 1·5

It is interesting to note that the labouring men noted above, though, generally speaking, doing harder work, eat more of the less economical food principle (using " economical " purely in its energy-producing sense) than those doing less work, who are probably more affluent. Amongst soldier's peace-time rations we find the following variations :

British	(3,400) 1 to 3·7
United States	(3,536) 1 to 5
German	(3,205) 1 to 8
French	(3,426) 1 to 9
Austrian	(2,886) 1 to 16
Russian	(3,297) 1 to 18

The differences here are largely due to the fact that the British and American armies are recruited more largely from townsmen; the continental armies, on the other hand, to a greater extent from the agricultural classes. Social as well as economical considerations arise, therefore, in connection with the decision on this point. A ratio of 1 to 8 may be taken as a fair average proportion.

Calculating on this basis, we will allot the remaining energy required to be furnished—that is, 2,500 Calories—to fats and carbohydrates in the proportion of $1 \times 9{\cdot}3$ to $8 \times 4{\cdot}1$, which gives us roughly 60 grammes fat to 480 grammes carbohydrates. The entire ration then stands as follows, viz.:

Protein	120 grammes =	490 Calories.
Fat	60 grammes =	560 Calories.
Carbohydrates ..	480 grammes =	1,970 Calories.

Total Calories in round numbers = 3,020

The above may be taken as a fair standard diet for an ordinary man doing light work and drawing average wages.

Before going any farther it will be useful to translate the above figures into actual foodstuffs. In doing this it is well to begin with the carbohydrates, since these are procurable from the vegetable kingdom only; 480 grammes of carbohydrates are contained in, roughly speaking, twice that weight of bread, which may be looked on as the staple article of carbohydrate food. The dietary, therefore, commences with 960 grammes of bread. This amount, however, supplies not only the total amount of carbohydrate, but also some of the protein and the fat. The amounts of these principles present in the above weight of bread are, in round numbers, 60 and 10 grammes respectively. Coming next to consider the protein, it is clear that the residue (60 grammes) will in most cases be supplied in the form of animal food; 60 grammes of protein are contained in 300 grammes of ordinary "medium fat" beef without bone, or, say, 375 grammes with bone. In addition to supplying protein, however, this weight of beef contains about 1·5 per cent. of fat, or, say, 6½ grammes. It only remains now to furnish the residue of the fat, say, 45 grammes, which will

be supplied by 60 grammes of butter. The whole dietary will then stand as follows :

Bread, 960 grammes (2 pounds 2 ounces).
Beef, medium fat, with bone, 375 grammes (13½ ounces).
Butter, 60 grammes (2 ounces).

(All the above calculations are purposely made in round figures for convenience.)

Before leaving this subject of a standard diet, I should like to utter a word of warning. The expressions "protein," "fats," and "carbohydrates," are purely chemical, and in no way culinary. They are convenient expressions to use when making the purely chemical calculations on which any scientific dietary must be based. They are extremely dangerous symbols if resorted to under any other circumstances. The student must remember that man does not eat proteins, fats, and carbohydrates, but meat, butter, bread, and sugar, and, therefore, whilst it is allowable to think in the former terms, he must always be ready to translate these expressions into actual concrete foodstuffs. I have given the above example of such a translation, as I have found it, on the whole, the easiest to follow, but any other will doubtless do as well, with the aid of some table of food values, such as that written by Atwater and Bryant, if only the above caution is kept in mind.

Since the amount of food consumed must depend on the amount of work done, it is necessary to inquire into the lines on which the demand for an expenditure of energy greater than 3,000 Calories should be met. For this purpose I will take the case of a man performing an amount of work which raises his daily demand for food to 4,500 Calories. The readiest way to effect such an increase is clearly to make an addition to the fat ration, since here we get the greatest amount of energy per unit increment of weight. The absolute limit of fat that can be tolerated by the digestive organs is partly a question of idiosyncrasy, and partly one of the severity of the climatic conditions to which the individual is exposed, taken together with the work done. The highest figures on record are 363 grammes and 365 grammes consumed by teamsters and brick-makers respectively in Massachusetts. The total energy demand

in the case of these men was 7,800 and 8,848 Calories respectively, and such a demand is, of course, quite exceptional. Ordinarily speaking, few people care to consume more than from 160 to 200 grammes of fat, even when doing as much work as in the case actually under consideration.

The first step, then, would be to increase the fat to 180 grammes, supplying thus about 1,100 Calories additional to the 3,000 in the original dietary. There remain now about 400 Calories to be provided from proteins and carbohydrates. Since the carbohydrate ration is already fairly high, it would be reasonable to divide this new increment equally between the two principles, giving 50 grammes of each. The entire scale would then run as follows :

Protein	.. ..	170 grammes = 697 Calories.
Fat	.. ..	180 grammes = 1,674 Calories.
Carbodydrate	..	530 grammes = 2,173 Calories.
Total	..	Rather over 4,500 Calories.

The additional foodstuffs required might be utilized to add a little variety to the dietary. The additional fat could be supplied in 4 ounces of bacon, 2 ounces of cheese, 4 ounces of oatmeal, and 1 pint of milk. These would also furnish almost all the additional protein required and all the carbohydrate. The amount of starchy food in such a dietary is, of course, excessive, and some of the carbohydrate would be usefully furnished in the form of jam and sugar.

CHAPTER VII

THE SOLDIER'S RATION

THE ration of the soldier is in all armies fixed by regulation at a certain amount. In deciding this amount regard is had, naturally, to the needs of the average man as regards fuel and tissue repair, but all choice of actual articles issued is taken out of the hands of the individual, and vested partly in those of the Supply Department, and partly in those of the regimental or company authorities who supervise the messing. This is one of the chief manifestations of the communal life led by the soldier, and at the outset no doubt a certain amount of "breaking in" has to be done in the case of individual recruits. This is, perhaps, less the case in the British Army than in the national armies of the continent, since the class from which our recruits are drawn is more homogeneous than is the case with those of other countries.

MESSING.—Some form of joint messing is now universal in our army, even in India. Up till quite lately in the latter country the soldier was allowed to have his individual ration prepared by the native cook, in the manner, and to a certain extent at the hours, which chimed in with his individual convenience. Such a custom is wasteful to the last degree, and from the sanitary point of view is also full of objection. The enormous multiplication of utensils used stood in the way of any satisfactory cleansing, and it is my firm opinion that a great deal of intestinal disease was attributable to the mistake of permitting this individualized form of messing. A combined messing system of some kind or other is necessary, but, though this is generally agreed upon, there is by no means a consensus of opinion as to the scale on which it should be maintained.

Briefly, the choice lies between a company and a battalion system as regards the infantry, and a squadron or regimental system in the cavalry. In the smaller self-contained units of other branches the question does not arise. This is not the place to discuss the arguments *pro* and *con* for the different methods, in as far as these are of a disciplinary nature. From the purely sanitary point of view the advantages are all on the side of the messing by large units as against that of messing by small units. In the first place, from the purely physiological point of view, there is less waste of foodstuffs, and the soldier receives, therefore, more actual nourishment from his ration. From the sanitary aspect it is obvious that the fewer the centres at which food is prepared and consumed, the less trouble there is in insuring that the former of these operations shall be carried out in a cleanly and orderly manner, and that the latter shall take place under the best surroundings as regards table adjuncts, cleanliness of utensils, etc. Lastly, the removal of kitchen refuse and slops is enormously simplified where these accumulate at one centre only, instead of several. This advantage would be most marked in warm climates, where flies are apt to haunt the neighbourhood of the cook-house. The full advantages of a regimental system can only be experienced where, as is the case in the most modern barracks, the battalion or regiment is provided with a common dining-room. Even where this is not the case, however, it is possible to arrange a battalion system of messing if it is really desired to do so ; and I consider that it is the duty of all medical officers to impress, by all means in their power, the sanitary advantages of such a system on commanding officers with whom they come into contact.

Cooking.—The only point which I should like to emphasize in this direction is the absolute necessity in foreign stations of excluding all native cooks from any share in handling the food. With a properly constructed kitchen, the British soldier can do the actual cooking in a great many Indian stations all the year, and in almost all (I might say, in reality, all the important stations) for a considerable portion of the year. In those stations where it is too hot for him to take part in the kitchen work, or during those

parts of the year in which this is impossible, the making up of the various dishes should be carried out by Europeans. The part played by the native cook should be limited to that of fire-boy or stoker. No part of the person of this usually dirty and invariably low-caste individual should ever be allowed to come into contact with any foodstuff before, during, or after preparation.

Peace Rations.—The peace ration of the British soldier at home consists of 1 pound of bread and ¾ pound of fresh meat, with bone, or 1 pound "nominal" preserved meat. (As this expression "nominal" in relation to the weight of preserved meat is of frequent use, I may as well give the explanation of its meaning here. In the trade preserved meat is sold in tins of a gross weight of one or more pounds, this gross weight including that not only of the meat, but of the tin in which it is packed. In the case of a 1-pound tin the net weight of the meat supplied is about 13 ounces. The larger the tin, the less the weight of the metal relatively to that of the food which it contains.) The fresh meat is either home-killed or imported "frozen," and as a rule the supply authorities stipulate that the latter shall not be issued on more than a certain number of days in the week. Mutton is given once a week ; on other days beef is supplied. Preserved meat is issued occasionally (generally once a month), for the purpose of effecting a turnover of the reserves in store. At stations abroad the fresh-meat ration is increased by 4 ounces, and a similar addition is made when the men are under canvas at home, or (subject to the approval of the G.O.C.) when they are temporarily accommodated in unequipped buildings.

In addition to the issue of bread and meat in kind a "messing allowance" of threepence a day is given to all European soldiers, other than Maltese, and is drawn for every man, from the day of attestation, for all days on which the soldier draws his pay, except when he is in hospital on account of injuries or ailments not due to active service, or under treatment in a non-dieted hospital, or in quarters, and receiving certain "medical comforts."

The total amount of food actually supplied to the soldier, therefore, amounts to his share of the pooled rations in kind, plus his share of the extra messing provided by the pooled

threepences of his company or battalion. The actual energy value provided naturally varies, but Pembrey and Parker, after an analysis of the messing-books of several units, came to the conclusion that the average amounts were as follows : viz., Protein, 133 grammes ; fats, 115 grammes ; and carbohydrates, 427 grammes—with an energy value of 3,280 Calories. In addition to this most men procure something in the way of supper, on payment, from the regimental institute or elsewhere, which represents a further meat allowance.

The ration of the man in the ranks may be said to be equivalent to that of a well-to-do artisan doing moderate work. The fat-carbohydrate ratio is, however, higher than is at all usual in the class from which the soldier comes, and the protein allowance is also high in comparison.

In the American Army the fresh-meat ration is 1¼ pounds, and that of preserved meat 1 pound. Fish, dried, pickled, or tinned, can also be substituted for the meat ration, but the weight allowed is only 14, 18, and 16 ounces in the three cases respectively. The usual bread ration is 18 ounces, but apparently a flour ration of the same weight is more usually issued. A special vegetable issue of potatoes (1¼ pounds) and beans (2·4 ounces), with a fair list of equivalent substitutes, is allowed, and in addition coffee or tea, condensed milk, and sugar (3·2 ounces). Various condiments and other adjuncts are also given. The ration of the United States soldier is thus decidedly generous. Its chief merit, however, is its great variability. Thus, by choosing certain articles, it is possible to increase the energy value to over 5,000 Calories, whilst with a different selection it may be allowed to drop to 2,500. The average composition is given by Havard at—Protein, 157 grammes ; fats, 99 grammes ; and carbohydrates, 481 grammes—with an energy value of 3,536 Calories. Extra messing is sometimes allowed from the company fund.

The difference between the British and United States rations is not very great. The greater variety in the scale shown in the latter is an advantage that is more apparent than real. The less a peace-time ration is tied down to definite quantities of definite foodstuffs, the better. Meat, and bread or flour, the most important constituents of any

dietary, are preferably procured in bulk and issued in kind, on account of economy. All condiments, stimulants, and other accessories, such as tea, sugar, and vegetables, are far better purchased as required by the messing authorities. The regimental messing system has clearly the advantage in this direction over the company system that all large purchasers have over small customers. They are able to exercise more discretion in their purchases, and their custom is better worth the having.

The German soldier receives a peace ration on two scales, the "lower" and the "higher" (*Kleiner-Friedens-Verpflegungssatz* and *Grosser Friedens-Verpflegungssatz*). Each of these consists of three portions—the bread, meat, and vegetable ration respectively. The bread ration is the same in both cases—viz., 750 grammes (1 pound 2¼ ounces) of bread, 500 grammes (1 pound 1½ ounces) of field biscuit, or 400 grammes (14 ounces) of egg biscuit. The meat ration consists of 180 grammes (6½ ounces) of fresh meat, or 120 grammes (4¾ ounces) smoked bacon, or 100 grammes (3½ ounces) preserved meat, with 40 grammes (1½ ounces) of ox-kidney fat, on the lower scale; and of 250 grammes (½ pound) of fresh meat with 60 grammes (2 ounces) of kidney fat, or 200 grammes (7 ounces) of smoked bacon, or 200 grammes of preserved meat, on the higher scale. The vegetable ration includes a large number of different vegetables—potatoes, lentils, rice, groats, etc. The weight of potatoes allowed is considerable, 1,500 grammes (3·3 pounds). The larger scale allows of more variety, but does not give any extra amount. The total composition is given by Bischoff at—Protein, 78·5 grammes; fat, 54·3 grammes; and carbohydrates, 514·8 grammes—energy value, 2,938 Calories, on the lower scale; and protein, 89·9 grammes; fats, 80·7 grammes; carbohydrates, 514·8 grammes—with an energy value of 3,230 Calories, on the higher.

The Austrian ration includes 840 grammes (1 pound 14 ounces) of bread, of which one-sixth may be replaced by 84 grammes (3 ounces) of biscuit, 190 grammes (6¾ ounces) of fresh meat, and a certain allowance of vegetables—*e.g.*, potatoes, 560 grammes (1 pound 4 ounces)—with salt, pepper, and vinegar. A special fat ration of 10 grammes (⅓ ounce) of lard, or 20 grammes of marrow fat, is also

allowed. In addition to these issues in kind, a small sum is allowed (10·5 hellers = about one penny) to provide breakfast and supper. The total ration amounts, according to Bischoff, to—Protein, 96·5 grammes; fats, 33 grammes; and carbohydrates, 532 grammes—with an energy value of 2,886·5 Calories.

In the French Army the ration of bread consists of 750 grammes (1 pound 2¼ ounces) of ration bread, and one-third that amount of *pain de soupe*. In place of this, *pain biscuité* may be ordered, in which case the weight of ration bread is only 700 grammes, the allowance of *pain biscuité de soupe* being 250 grammes. A third alternative is *pain de guerre*, which corresponds more exactly to our "biscuit," in quantities of 550 and 185 grammes (1 pound 3½ ounces and 6½ ounces) respectively. *Pain biscuité* is bread which has has been exposed to prolonged baking. It is a good deal drier than ordinary ration bread (*pain de munition*), the crumb being closer in texture and the crust browner. It can be kept for eighteen to twenty days after issue, but if "leaven" is used in the process of manufacture, this period is shortened to ten days. The meat issue is represented by 320 grammes (11½ ounces) of fresh meat with bone, or 200 grammes (7 ounces) of preserved meat, or 240 grammes (8½ ounces) of salt pork. Thirty grammes (1 ounce) of rice, or 60 grammes (2 ounces) of dried vegetables, or 30 grammes of preserved vegetables, or 60 grammes of preserved soup, are also allowed, with 30 grammes of lard, or 40 grammes of beef fat. A small issue of salt, sugar, and roast coffee is made, and on occasion ¼ litre (9 ounces) of wine, or 2¼ ounces of brandy. A special ration of 11¼ ounces of brandy is allowed as a *ration hygienique*. A very considerable latitude is given in the matter of substitutes. Lemoine gives the average composition as being—Protein, 37·31 grammes; fat, 66·07 grammes; and carbohydrates, 561·2 grammes—with an energy value of 2,927 Calories.

In the Russian Army the ration is extremely varied. This is partly due to the enormous number of fast days that are observed by the men. The basis of the diet is 1,230 grammes of bread (2 pounds 12 ounces), with tea and a little sugar. A certain money allowance is also made to cover the purchase of meat, vegetables, salt, etc. The

average composition and energy value are given by Bischoff as—Protein, 120·7 grammes ; fat, 39·2 grammes ; and carbohydrates, 628 grammes—with an energy value of 3,417 Calories. On fast days, by a judicious selection of foodstuffs, the protein is raised to 125 grammes, the fat to 54·9 grammes, and the carbohydrates to 669·8 grammes. The energy value of the ration is raised to 3,770 Calories. The apparent paradox is explained by the fact that the fasting is one of quality only, and amounts to deprivation of meat. As a result, there is more cash left over from the money allowance for the purchase of the cheaper foodstuffs.

CHAPTER VIII

FIELD-SERVICE RATIONS

THE ration of the soldier on field service is always and inevitably a compromise between the amount that he needs and that which the supply authorities can see their way to providing. The latter, again, is also a compromise between the amount that can be furnished from local resources and that which the transport can provide carriage for. These three factors make a graduated scale in which the soldier's needs stand at the top and the capabilities of the transport at the bottom. The actual ration, therefore, that the man in the ranks receives lies somewhere between the two extremes just stated, and more often below than above the mean of the two. All countries lay down scales of rations for field service, graduated, in some cases, according to the amount of work that the soldier will be called on to perform ; but it is not to be supposed that any commander would recognize this scale as absolutely binding upon him should the local resources enable him to increase, or other exigencies compel him to diminish, the actual amounts prescribed by the Regulations. These scales must be looked on as being merely guides to the average amounts that have to be calculated for, principally with a view to transport, not by any means as Procrustean rules to which the appetites of the army are compelled to conform.

It may often occur that at the very time when the troops are being called on for extreme exertions the difficulties of transport and supply may be so great that the ration may have perforce to be reduced to a level insufficient to meet the physiological demand. A striking instance of this occurred in the German campaign in South-West Africa (1904-1906), where it was frequently found impossible to supply the movable columns with even a reduced (two-thirds) ration. The condition of affairs in such cases is aggravated by the fact that the difficulty of transport does

not apply equally to all constituents of a ration. Fresh meat can be driven "on the hoof," and preserved meat is peculiarly portable; but the carbohydrate foodstuffs do not possess the former advantage, and are, besides, extremely bulky. Under such circumstances the men may be reduced to a ration consisting largely of meat, the amount of which that can be metabolized is strictly limited by the capacity of the digestive organs to supply the necessary ferments.

Field-service rations may be divided into normal, special, iron or reserve, and emergency rations, and will be considered under the above heads.

The normal ration is the scale laid down for ordinary field operations. The special ration is designed to meet some special emergency calling for extreme exertion. This may be achieved by the addition of some special articles or the increase *pro rata* of all the constituents of the normal ration. Some services prescribe more than one such scale. The iron or reserve ration is a ration which is intended to supply a fair amount of energy, not sufficient to meet all demands, but enough to enable the soldier to live and work, while subsisting on the reserve stores of energy contained in the stored-up glycogen and fat or the protein of the less active tissues. Such rations are carried by the man or in the regimental transport, and are not allowed to be consumed without the sanction of superior authority. The emergency ration is an artificial compound, carried on the man, intended to keep "body and soul together" when all other forms of nutriment fail. The soldier is not permitted to eat this ration except by order or in dire emergency.

The Normal-Service Ration.—The different scales laid down for the more important armies are shown in the Appendix.* The basis of all such rations is a meat and bread or biscuit issue, supplemented by vegetables, tea, and sugar. This last article is supplied as such and also as a constituent of jam or preserved fruits. Usually a special fat ration is given.

Field-Service Ration, British Army.—The meat-and-bread basis of this ration appears to have a traditional

* The tables and plate referred to in this chapter are given in the Appendix for convenience of comparison.

foundation, the normal issue during the Napoleonic wars being much the same as that in the South African campaign. The total value of the ration was fixed empirically, and it does not appear that, till quite lately, a definite experimental trial was made to see exactly how much food was necessary to support the fatigues of a campaign. In the year 1909, however, such an experiment was sanctioned. This was conducted on the following lines : A party, consisting of one officer and twenty N.C.O.'s and men of the Loyal North Lancashire Regiment, with three medical officers and some details, was encamped on Salisbury Plain from the 11th to 23rd October. The food was carefully restricted to the issues laid down in allowance regulations, and a certain march, in heavy marching order, carried out every day. A careful record was kept of the actual ground covered, and an estimate of the energy so expended made, on the lines detailed in the chapter on "The March." An estimate of the energy otherwise expended was also made, and this was fixed at 3,000 Calories. This arbitrary figure was arrived at by taking Zuntz's estimate for a purely sedentary life, giving a mean of about 2,350 Calories as a basis, and adding to it an amount considered to be fairly equivalent to the exertion demanded by the ordinary fatigues of camp life, under the peculiar circumstances of the experiment. The men were carefully weighed every morning at the same hour and in the same minimum of clothing. At the commencement, on the middle day, and at the termination of the experiment the measurement round the chest, the abdomen, and calf were also recorded. Taking the purely theoretical calculation first, it will be noted (Table B) that there was a decided deficit of nearly 900 Calories per diem. Obviously this calculation is liable to the objection that the extent of the defect is largely proportional to the amount fixed on as representing internal work. The energy value of the food was estimated partly by means of analyses carried out in the Royal Army Medical College and partly from the figures given by Atwater and Bryant in "The Chemical Composition of American Food Materials." A strict watch was kept to see that no food refuse was left unaccounted for. The actual composition of the rations eaten is shown in Table C. The diurnal

variation in weight is shown by the curve on Plate D. It will be noted that there was a distinct initial rise, lasting over the first four days of the experiment, followed by a marked and much greater fall. The initial rise affected all but two of the men, and cannot be regarded as accidental. It may have been due to a greater retention of water in the tissues, the result of a salt-meat ration, or to the fact that the carbohydrate in the ration was considerably higher than that in the usual barrack ration, or, again, to the stimulus to muscle growth supplied by the regular exercise. This increase in weight was coincident with an increase in the abdominal girth, and the calf measurement, but a decrease in the circumference of the chest. Following on this unexplained rise was an even more marked, and almost equally general, fall, accompanied by a diminution in chest and abdominal measurements, and a very slight rise in calf circumference. The men at the conclusion of the march showed a pinched, starved appearance, and signs were not wanting to show that most of them, and more particularly the heavier members of the party, had come close to an end of their reserve stores of fat. Whether the theoretical calculation of the amount of energy expended was correct or not, it was abundantly clear that the amount of food consumed was by no means adequate to the amount of work done. At the same time it was certain that the work done did not in any way come near to the demands that normally must be expected under field-service conditions. The life led by the men was roughly as follows : After rising about 7 a.m., they had their breakfasts, and were then weighed. After putting on their accoutrements, they marched a distance varying from eight to twenty miles, the general average distance covered being about twelve miles. The remainder of the day, after return to camp, was filled up in any way the men chose, so long as they did not leave the camp boundary. At the beginning of the experiment they used to kick a football about, but as they became jaded towards the end of the fortnight, they left off this amusement. The tents had to be pitched on the first day, and were struck moved by hand about 500 yards, and repitched in a mor, sheltered position on the third day. On the eighth day thee were struck, loaded on to a waggon, and then unloaded in

the forenoon, again loaded in the afternoon, and unloaded and pitched at a new camp in the evening. On the ninth day they were struck and loaded in the morning, unloaded and pitched in the evening. At the first camp-ground the latrines were about one-quarter of a mile distant, and 50 feet below the camp. In addition, the ordinary camp fatigues of fetching meals from the somewhat distant kitchen, etc., had to be performed. There was no night duty, no manœuvring, meals were regular, and consumed under comparatively comfortable conditions, and, generally speaking, the men were not harassed in any way. Clearly, the exertions of a life like the above cannot in any way be held to come up to those of even ordinary campaigning. Whether the theoretical calculations, then, were absolutely accurate or not, it is fairly clear that the ration issued was insufficient under the actual circumstances, and *a priori*, therefore insufficient to meet the normal demands of war. The food principle the lack of which was most felt was fat. As will be seen, during the first week, whilst tinned beef was issued, this fell as low as 50 grammes. In the second week, as a result of the very high quality of the fresh meat supplied, the amount of this particular ingredient rose to 110 grammes ; but even this allowance was insufficient to allay the marked craving which was felt by all, more especially by the officers of the party—a craving that persisted in the case of the writer for upwards of a fortnight after a return to normal conditions of life. A marked craving for sugar was also experienced, but not nearly so strongly as in the case of fat. Generally speaking, the carbohydrate ration was held to be sufficient. The officers were unable to consume their biscuit ration, though the biscuits were of excellent quality, and liked by them. Presumably this was due to social dietetic custom. The men ate all of theirs, and preferred them to the bread given in the second week. This was probably due to the fact that the bread could be bolted, and did not, therefore, last so long as the harder biscuits, which demanded a considerable length of time for their mastication. The men described them as being "more filling." There was no general desire for more meat, and towards the end of the first week there was in some cases, especially amongst the officers, a distinct

loathing for the corned beef. This was probably due to the monotonous nature of the issue and the absence of condiments. The vegetable ration was considered unsatisfactory. The energy value supplied in the case of fresh vegetables is incommensurate with the weight, and since on service these articles are only available for issue in localities where they are actually grown, being unable to stand transport, their inclusion in the energy-supplying portion of a ration seems inappropriate. As a result of this experimental march, a suggestion was put forward that certain additions should be made to the scale, consisting of 2 ounces of bacon, 2 ounces of cheese, 4 ounces of jam (making the total ration ½ pound actual), and 2 ounces of oatmeal. It was calculated that these additions would raise the value of the whole ration to about 4,500 Calories, which, on theoretical grounds, appears to be about the average expenditure per day under field-service conditions.

In accordance with this report a second experimental march was ordered to be carried out in August, 1910. The strength of the party was the same as before, taken on this occasion from the Somerset Light Infantry, with an additional officer belonging to the Army Service Corps. The general routine of the march was also much the same, except that, owing to local difficulties in the matter of suitable camp-grounds, and also to the weather, the tents were not moved after they were pitched on the first day. The men were thus saved a considerable amount of fatigues, and as the kitchen and latrines were more conveniently situated than in the first case, the estimate for internal work was lowered to 2,750 Calories for marching days, and 3,000 Calories for days on which no march was performed. Here, again, there is the obvious objection that the ultimate balance of food supplied and energy expended depended very largely on an arbitrary calculation. The same observations were made as before, but the measurements of chest, abdomen, and calf were carried out more frequently. The composition and energy value of the food is given in Table E, and the preponderance in fat over the diet of the first march is very striking. As on the first occasion, all members of the party practically showed an initial rise, but this was more marked on the second than

on the first occasion. This rise was followed, as before, by a fall ; but here, again, the fall was less in extent than that which marked the second stage of the first experiment. Lastly, the average weight finished off much where it began, the slight gain which was, in fact, recorded, being negligible. The condition of the men exhibited a marked contrast to that of the men who took part in the 1909 experiment. There was no sign of wasting, and, in marked contradiction to the hunger experienced at the conclusion of the first march, two of the officers who participated in both complained of loss of appetite. This was probably due to the high protein ration.

Taken together, the two experiments are very instructive. The conditions were as nearly identical as could be expected under the circumstances. The men were of the same average physical standard as regards weight, age, etc., and no special selection was made as regards habits. In both cases they were taken at random from a considerably larger number who volunteered to share in the experiment. The actual marches were rather harder on the second than on the first occasion, though the average work done per diem (see Table F) was rather less, since one extra day of rest had to be given on account of bad weather. In both cases the weather was extremely inclement, and on the second this fact was aggravated by the situation of the camp, which was on an exposed hillside, at about 1,000 feet elevation.

Discarding minor differences, it may be said that, the energy expenditure being much the same on both occasions, this was not met by the ration issued during the first experiment, whilst it was satisfactorily replaced by that issued on the second. As already stated, the work done was not so severe as that which would be demanded of men under ordinary conditions in the field, but the results obtained furnish us with some basis for argument on this point. The average distance traversed was twelve miles per day. By itself this is not severe exertion, though under the ordinary conditions of a campaign, when the men would be unable, as they were during these experiments, to take their ease after arrival in camp, such a distance would be considered a satisfactory and sufficient demand to make on

men in the absence of any specially urgent necessity for speed of movement. The addition of another five to six miles per day would, even with the possibility of immediate rest on arrival in Camp, have meant severe work, and I have come to the conclusion, after discussing the question with several staff and regimental officers, that such a distance would about represent the extra work entailed by the ordinary camp duties that devolve on men before starting in the morning and after arrival in camp in the evening. Taking the average expenditure per mile of a give-and-take road at about 90 Calories (see p. 52), a distance of five and a half miles will represent 500 Calories.

Since in the second march it was found that a ration supplying an average net amount of 4,000 Calories was sufficient to meet the energy demands of the occasion, it is a fair inference that one of 4,500 Calories would be needed to meet those of active service, whilst possibilities of expansion to, say, 5,000 Calories should be readily available.

If Table A be consulted, it will be seen that the normal field rations of the different continental nations in no case, except the Russian, in any way approach the above standard. The reason of this is that the scales which the different authorities fix are intended to lay down a minimum for actual subsistence in a country where other supplies are locally available. In the South-West African campaign the normal German rations for troops on the lines of communication was—Protein, 172 grammes ; fat, 123 grammes ; and carbohydrates, 633 grammes—with an energy value of 4,360 Calories. This is higher by about 700 Calories than their regulation issue for hard work in a (presumably) European campaign. For troops at a distance from the lines of rail the ration had to be reduced to about two-thirds of the normal issue. The average composition of this reduced ration was 132 to 139 grammes of protein, 76 to 95 grammes of fat, and 411 to 490 grammes of carbohydrates. The energy value varied from 2,940 to 3,494 Calories. The necessity of allowing a smaller ration to the working than to the stationary troops was unavoidable under the conditions of the campaign, and it had the advantage that the men on return from the " trek " had the chance of recuperating on a liberal diet.

From a British point of view, all the field-service rations of foreign armies are lacking in fat, though, as a matter of fact, they all make a special issue of fat or lard. The Russian soldier is peculiarly badly off in this respect. The allowance of protein is also low for men who are exposed to vicissitudes of climate and the general strain, physical and mental, of war.

Special Rations.—These are rations intended to be issued on the order of superior authority to meet the energy demands of some peculiar emergency. In the German Army the meat or vegetable issues, or both, are increased; in the French a definite addition of meat, bread, and brandy is made to the normal ration, to make what is termed the *ration forte*. Either the normal or the "strong" ration may be augmented by a *pro rata* increase of one-quarter, one-third, or one-half of all its constituents. The above methods are those which strike one at first sight as being those most logically adapted to meet the situation. It is doubtful, however, in my mind if they really do solve the problem in the best way. The conditions under which an increased ration is demanded are often those which render the consumption of that ration a matter of difficulty. Either the men are too tired to eat their food, or there are no facilities for its preparation. In my opinion the demands imposed by increased exertion should be met by the special addition to the ration of some foodstuff which needs the minimum amount of preparation, to which the soldier is unaccustomed, and which will possess, therefore, the advantage of novelty. Some form of meat extract would be advisable on such occasions, with good chocolate or toffee, and perhaps something in the nature of a sausage. It is not much satisfaction to a man who has lived on tinned beef and biscuit for a fortnight, when he arrives very tired at the end of a long march to be presented with an extra half-tin of the former and four more of the latter. A mess-tin of hot soup, though it contains no actual nourishment, would be more appreciated than the meat, and the sugar of the sweetmeat would be preferred to the starchy carbohydrate of the biscuit. It is most important, I think, to remember on service—more, even, than at ordinary times—that the thing which really counts is not how much food the man

receives from the supply authorities, but the amount of that food which he can turn to useful purpose. When the digestive and assimilative powers are depressed, as they so often must inevitably be on service, there is neither sense nor reason in merely piling more food on to the man. This is more especially the case when the additions to the ration are identical with those foodstuffs of which the man is already, in all probability, heartily sick.

The composition and energy value of some special rations is given in Table G.

All rations, whether normal or special, must rely for the greater part of the energy which they supply on a basis of meat, fresh or preserved, and bread or biscuit. As regards fresh meat, our issue is greater than that of any other European army. This difference is, in my opinion, entirely in our favour. One pound of fresh meat (1¼ pounds including bone) is not in any way an excessive allowance for an actively employed young man. From the physiological point of view the processes of metabolism should be kept at a high level, to enable the individual to face the mental and physical stress of active service.

Whatever may be the theoretical advantages of a low protein diet in the case of the sedentary man, I am absolutely certain that for the fighting man, exposed to the incessant physical and mental strain of war, the only suitable ration is that which contains a large amount of protein, and, further, I am certain that that protein should be furnished, as far as possible, in the form of fresh meat. Unfortunately, the conditions under which the British Army campaigns are not such as to facilitate the issue of fresh meat, while, when this is possible, the meat supplied is often coarse and tough in fibre, and tasteless. The chief defect is, however, in the direction of fat. The German report on the campaign in South-West Africa allows only 1 per cent. of fat in the fresh meat supplied, or about half that given by Atwater for "very lean" side of beef. This defect can be met by a special issue of fat, either as such—*e.g.*, lard, kidney fat, etc.—or in the form of bacon or cheese. The issue of mincing machines will do much to overcome the toughness and coarseness of the fibre, whilst as regards the complaint of tastelessness, this might be well

met by the issue on such occasions of some preserved meat extract. The important stimulant action exercised on the digestive processes by the extractives of meat has been well shown by Pavlov, and the work of Thompson of Dublin has confirmed these conclusions. They would undoubtedly play a very useful rôle under the conditions which I have just mentioned.

The ration of preserved meat is, to a certain extent, fixed for us by trade conditions, since our supplies are procured in the open market. Nations which have their own military preserved-meat factories have a freer hand in the matter. Our ration is, therefore, decidedly larger than theirs, and here, again, I consider the difference is in our favour, for the reasons which I have already stated. The ration is issued in 1-pound (nominal) tins, containing about 13 ounces of meat. Certain conditions are laid down as to the proportion of fat that should accompany the meat—viz., between 10 and 15 per cent. This corresponds to the amount present in fresh meat classed as "lean," and is probably greater than the proportion found on the fresh meat usually obtainable on service; it is undoubtedly too low, in the absence of a special fat issue. On the other hand, it is impossible to place it higher, since, with a larger proportion of fat, the meat fibre becomes greasy and nauseating. This is, of course, particularly the case in a hot climate, when the fat becomes liquid. The corollary is the provision of a special fat issue. It is important that the meat should be issued in single rations, since then each man can carry his daily ration on his person. With larger tins, either one man has to carry his comrades' allowance, or else the tin has to be kept open in the haversack for one or more days, according to the size of the tin—an obviously objectionable practice. In the South-West African campaign the Germans made a rule that 75 per cent. of the meat should be packed in single, the remainder in triple, ration tins. The French use single ration tins only, except in the case of fortresses, to which larger tins (2 kilos) are issued.

The German War Department has its own preserved-meat factories, situated at Mainz and Spandau; but it does not rely entirely on this source of supply, the open market

being also utilized. The army factories manufacture two kinds of preserved meat—beef in bouillon, and *Gulasch*, a sort of stew of beef or mutton, with bacon, vegetables, etc. Beef must be of the first quality only, from animals four to seven years old, and of these only the fore-quarters are used.

In both the French and German Armies the meat is well cooked before tinning, and the bouillon is added to the meat in the tin, the whole being seasoned ; in the latter case vegetables are included. In the French ration the meat is pressed into the tins and the bouillon concentrated. The French use pork as well as beef for the preparation of a ration of this kind. In these armies the aim seems to be to procure a complete ration, as opposed to the meat portion of a ration only. Under the strict rules that can be enforced in a Government factory this is no doubt feasible, but dealing in the open market the purchaser is often apt to be defrauded in the matter of this class of preparation. The Germans in South-West Africa found that a tin reputed to hold 400 grammes of mixed preserves sometimes contained only 100 grammes meat, with a few vegetables floating in 300 grammes of fluid.

The relation of bread to biscuit is much the same as that of fresh meat to preserved meat. The younger men can, as a rule, consume all their biscuit ration ; but older men and officers find considerable difficulty in doing so. The present ration biscuit, weighing 2 ounces, is an excellent specimen of its kind, but presents the natural difficulty of being hard, and taking time to masticate. The French Army makes use of a *pain biscuité*, which is simply bread desiccated by prolonged heating. Such a bread has, doubtless, many advantages over biscuit, but possesses one marked disadvantage, and that is its friability. A biscuit can be carried in the haversack, and small pieces broken off at intervals and chewed. Dried bread in the haversack rapidly gets reduced to the condition of powdered crumbs, and is then of no further use to anybody. The portability of biscuit is its great recommendation, and though its hardness is a distinct disadvantage, especially to people with bad teeth, still, the fact that it cannot, like bread, be bolted at one meal is a considerable make-weight

on the other side. In the German and Austrian Armies an egg biscuit is made use of, containing 500 eggs to 100 kilogrammes (220 pounds) of flour ; 12 kilogrammes of sugar, and 12 litres of milk are also added. Such biscuits possess, of course, a considerably enhanced energy value, owing to the fat present. I should be doubtful of their keeping qualities, especially in respect of the attacks of weevils, etc., and am inclined, on *a priori* grounds, to suspect that men would soon get tired of them. For prolonged use, there is no doubt that the simpler the food the better. The bread and biscuit issues of the continental armies are considerably larger than our own. The bread ration of the Russian soldier is the highest, and the faculty of disposing of such a large amount of starchy food must be in some way a national idiosyncrasy.

Vegetables.—These are issued either fresh or preserved. The distinction is important. Fresh vegetables are especially valuable on account of their antiscorbutic properties. This is possessed most markedly by the green vegetables, cabbages and the like, though also by onions and potatoes in considerable degree. The class first mentioned, owing to the presence of a large amount of indigestible cellulose, also exercise an important influence on the peristalsis of the intestine. Unfortunately, no fresh vegetables, with the exception of onions and potatoes, keep well, whilst these, owing to the large amount of water that they contain, are disproportionately bulky, when considered in connection with the amount of energy that they are able to furnish. When, therefore, it is a case of transport, green vegetables are out of the question, whilst potatoes and onions can be carried just as well dried as fresh, and a great saving of weight thereby effected. Where fresh vegetables are procurable, they should be supplied as extra to the ordinary ration, and no account taken of the trifling amount of energy that they contain. Among vegetables with a distinct nutritive value, the most important are peas, beans, and lentils. These keep well when dried, but possess the great disadvantage that prolonged soaking is necessary before cooking to render them digestible. Where travelling kitchens are available, this difficulty can be easily remedied ; but in their absence these leguminous vegetables lose much

of their value. Potatoes dried in chips are extremely useful. They keep well, and can be easily fried or mashed, and make thus an excellent addition to the meat ration. Great care must be taken in allowing the men to eat uncooked fresh vegetables. The methods of intensive cultivation in vogue in certain countries in respect of these foodstuffs are such that disease is almost certain to result if they are eaten raw. The consumption of salads or of thin-skinned fruits such as strawberries should be forbidden, and the rule as far as possible enforced.

Some special form of fat ration is the general rule. In the French Army this takes the form of lard or suet; in the German, of kidney fat; in the Austrian, of marrow fat or lard. Some such issue is most certainly necessary, since the meat usually procurable on service, whether fresh or tinned, does not furnish nearly enough of this important source of energy. It must be remembered that the common foodstuffs, milk and butter, which in peace-time supply so large an amount of the fat consumed, are rarely procurable in the field, owing to their lack of portability. The best form which the fat issue can take is that of bacon or cheese. These articles have the advantage that the former can be eaten with relish cold, which is hardly the case with lard or suet, whilst the latter, cheese, is also edible raw. At the same time they provide a certain amount of protein. In the case of cheese this protein is different from that of flesh meats, so that with the issue of this substance an important variety is introduced as regards this particular food principle. The importance of variety, especially in the case of proteins, has already been mentioned.

Sugar is given in all rations, but, except in the case of our army, in absolutely insufficient quantity. Jam seems not to be allowed by any foreign nation—a remarkable omission, since, in addition to the sugar present, some of the more acid jams have a marked antiscorbutic action. In South-West Africa the German troops found the augmented ration of 40 grammes of sugar too small. There is not the slightest doubt that in this respect our ration is far superior to any other. The advantage of sugar lies in the fact that it can be absorbed with the least possible alteration. There is no necessity for prolonged process of metabolism, as in

the case of the proteins, or of emulsification, and subsequent splitting up, as in the case of the fats. Sugar is, however, not only the most easily absorbed ; it is the most rapidly utilized of all the foodstuffs. A fairly large number of experiments have been made on the use of sugar during hard work, the most complete of which are those of Médecin-Major Joly, with two companies of the 94th Regiment of the Line of the French Army at Bar-le-Duc. It is true that there are not lacking dissentient voices, but I have been unable to find that their unfavourable views are as well founded as those which support the issue of the ration. My personal experience is entirely in favour of a high sugar issue. This foodstuff should, therefore, in my opinion, form a considerable bulk of any special ration, or of any addition to the normal ration, under conditions of peculiar exertion.

Stimulants.—These are issued by all armies, either as an emergent or as a regular ration. I have already stated my views as to the occasions on which alcohol should be issued. It certainly should not be given as a matter of routine, as was done in the case of the German campaign in South-West Africa. At the outset the allowance on that occasion was 3½ ounces a day, and, with a view to convenience of supply, presumably, the total amount for one week was given out at one time. The possession by each man of 24½ ounces of spirits led to aggravated drunkenness and violence. It was said, too, that the regular daily issue of alcohol conduced in some cases to the acquirement of the " drink habit " in men who had not previously suffered from this failing. It cannot be too strongly laid down that a daily issue of spirits is wrong. The value of alcohol on service, which is very great, lies in its being resorted to occasionally only. Constant use robs it of all benefit.

Tea is issued in our army, but the continental soldier prefers coffee, being more accustomed to it in his home. The British soldier likes tea in moderation, but does not, unfortunately, show any inclination to drinking it to the exclusion of other beverages like his Australasian cousins. If he could be trained to do so, the question of purification of water in the field would be considerably simplified.

Coffee is a less convenient article from the supply point of view than tea, since the ration is twice the weight of the tea ration. In addition, the preparation of coffee is a more difficult process. If the berry is issued unground, then coffee-mills must be supplied, as in the French Army The Germans in South-West Africa found the gun-butt a most ineffectual substitute.

Reserve Rations.—These are rations which are carried either by the soldier on his own person or packed in the regimental transport. They are intended to be used only by superior order, and when the connection with the normal chain of supply is broken. The conditions under which such rations will be needed are likely to be much more frequent in the wars of the future than in those of the past. Forty or fifty years ago the exigencies which demanded the issue of the reserve ration were chiefly due to difficulties of transport and rapid movement of the troops. Such occasions will also undoubtedly occur in the future, though the introduction of mechanical transport may be expected to render them less frequent. The increased range of modern armaments and the prolonged nature of modern battles will, however, give rise frequently to situations in which the men at the front may have to depend for all their food during a period of two or three days on the supplies which they carry on their own persons. There is no doubt that the provision of a good reserve ration would facilitate the solution of many strategical and tactical problems.

The question has a physiological side, and I propose to discuss it briefly from that point of view. The first point to be considered is the amount of energy that will be demanded of the man and the amount that can be supplied in the ration. The latter will depend, to a certain extent, on the weight which the man can afford to carry, the length of time that the ration is expected to last—in other words, the number of rations that must be carried—and, lastly, on the degree of concentration possible as regards the different foodstuffs.

The amount of energy required from the man will probably be, for reasons already stated, somewhere about 4,500 to 5,000 Calories per diem. Since, by the terms of the problem, the ration is required to meet a brief emergency, some

assistance may be expected from the tissue reserves of the body, and it will be unnecessary, therefore, to replace completely all the day's expenditure by means of the ration. On the other hand, since the emergency may quite well last as long as three days, it would be unwise to furnish less than, say, two-thirds of the daily output. This will leave the man at the end of three days what one may term "one day short" in his energy account. The ration should supply, therefore, about 3,000 Calories, and should be of such weight that a man can carry three rations. having a total weight of 6 pounds. The reason for settling on this last figure will be given when discussing equipment; here it need only be said that every ounce of weight that the man can spare will be needed for ammunition. The problem, then, reduces itself to the following statement—viz., the provision of 3,000 Calories in a weight of 2 pounds, or about 900 grammes. This means a degree of concentration in which every gramme provides $3\frac{1}{2}$ Calories.

A few words may here be said as to the exact meaning of the expression "concentration of food." There is only one way in which food can be concentrated, and yet retain all its energy-producing constituents, and that is by evaporation. If we drive off all the water from, say, a pound of lean meat, we will have as a residue about 90 grammes of protein; by stopping short of complete desiccation, and leaving a small amount of residual moisture—say, about one-eighth only of that originally present—we can, if the process be carried out carefully, produce a concentrated foodstuff, perfectly palatable, which will keep without being hermetically sealed almost indefinitely. Such a foodstuff will contain all the energy-providing constituents of the original meat and all its tissue-building elements, with the one important exception of water. As long as water is procurable, such a foodstuff is extremely valuable, and, therefore, on a forced march through a well-watered country much saving of transport might be effected by its issue. Unfortunately, there are many occasions on which a reserve ration is required, such as during a long-drawn-out attack, when it is just as difficult to send forward water to the men as it is to supply solid food. It must be remembered that water is of all foodstuffs the least portable and the

most bulky. We are, therefore, faced by the difficulty that in one of the emergencies in which, above all, we require a reserve ration we are unable to rely on concentration to help us in the solution of the problem. Concentration must always be carefully distinguished from extraction. There seems a general idea in the minds of the lay public—a belief fostered largely by sensational posters—that it is possible, by some abstruse process, to concentrate the entire energy value contained in the carcass of a slaughter beast into one teacup. It is well, therefore, to remember "extraction" means merely the taking out of certain soluble matters from the whole mass of foodstuff available, which have no real food value, though of great importance as digestive stimulants.

The only foodstuffs which lay themselves open usefully to concentration are meat and fresh vegetables. Bread becomes crumbly, and is in this condition best replaced by biscuit.

Since, however, whatever our reserve ration be, we must meet the energy demands inside the prescribed weight by a certain amount of concentration, it seems fairly clear that our first choice must light on those foodstuffs which we are accustomed to eat in a more or less water-free state rather than on those that normally contain a large proportion of moisture. This turns our attention at once on the fats and sugars. The basis of our ration, then, from an energy-forming point of view, must consist of these articles alone or in combination. As between the two, sugars are the more easily digested and absorbed, and, in addition, after absorption, the more readily made use of in the body. On the other hand, fats are to sugars in respect of their energy-producing powers as $2\frac{1}{4}$ to 1. A large allowance of protein is not necessary, since, as a form of energy, this is on a level with the sugars, and at the same time less easily digested. In choosing the various foodstuffs, we must limit ourselves to those that can be eaten raw, or, if already cooked, can be eaten with relish cold. As regards fats, no foodstuff consisting mainly of this substance can be eaten cold, with the exception of butter, which is peculiarly unsuitable for transport, especially if the climate is at all warm. The two foodstuffs which are

suitable vehicles of this principle are bacon and cheese, and these should undoubtedly be chosen. In addition to fat, the latter supplies a substantial amount of protein, and the former a little of the same substance. The sugar can be supplied as such, or as chocolate. The ordinary chocolate issued to the Royal Navy contains about 20 per cent. of sugar and 30 per cent. of fat. Substance can be added to the ration in the shape of biscuits, which supply both protein and carbohydrate. As a merely tentative sketch of such a ration, the following scale is suggested. It could be packed in a portable form, and, with salt and tea added, would be well within the necessary limits of weight. I should feel inclined to add some beef extract purely as a stimulant.

SUGGESTED SCALE FOR A RESERVE RATION.

Substance.	Weight (Avoir.).	Protein in Grammes.	Fats in Grammes.	Carbohydrates in Grammes.	Calories.
Biscuit ..	8 oz.	37	3	180	926
Bacon ..	4 oz.	11	76	—	756
Cheese ..	4 oz.	31	41	5	536
Sugar ..	3 oz.	—	—	70	290
Chocolate ..	3 oz.	7	25	50	450
Tea	¾ oz.	—	—	—	—
Total ..	1 lb. 6¾ oz.	86	145	305	2,960

The weight would be brought up to nearly 2 pounds, in all probability, by the metal tins or wrappings in which the various foodstuffs were packed for carriage. It seems to me that it is on lines something like the above that a reserve ration should be built up.

The composition of the various reserve rations of foreign armies is given in Table J. The haversack ration of the United States is the only one which appears to give an amount of energy at all equivalent to the amount likely to be demanded of the men under the conditions when a reserve ration is likely to be required.

Emergency rations are rations composed of highly concentrated foodstuffs, weighing very little, and supplying an

amount of energy that is not equivalent even to subsistence. They are not used to any great extent. That issued in our army weighs about 9 ounces, together with its enveloping tin, and supplies about 900 Calories. It consists of a mixture of Plasmon and chocolate.

Conclusion.—However many different scales of rations may be fixed for an army, that one which is of real and preponderating importance is the normal ration. This should be so fixed that a man at ordinary times is getting rather more than he really needs at the time itself. A great deal of war consists of "that important strategical operation, sitting still," and it is during the conduct of this operation that the soldier should be accumulating those reserves of energy which, since they are part of his living tissues, are always at his disposal, need no preparation, and cannot be lost by carelessness in the supervision of equipment. No harm can follow from high feeding if the men are compelled, as I have already said, when speaking of physical training, to keep themselves in good condition by regular exercise during these periods of "sitting still," whether in the form of play or drill. The soldier who is always getting enough, but only just enough, to eat will be so close to the edge of starvation that the first twenty-four hours on short rations will be felt by him. The well-fed man, trained rather big, will be able to tide over several days of starvation if only he has something in the way of a fairly substantial ration to stay the natural cravings of his gastric mucous membrane for occupation. The real solution of the reserve-ration problem lies not in the reserve ration itself, but in a liberal diet at all times when a liberal diet is procurable.

CHAPTER IX

WATER

Water, considered chemically, is a compound of hydrogen and oxygen, in the proportion of two volumes of the former to one of the latter. Considered physically, it is a fluid which is incompressible, and seeks to find its own level—points of great importance in connection with sanitary and hydraulic engineering. Further, it is odourless, tasteless, and, except when seen through a considerable depth, colourless. In respect of its reaction on the ordinary senses of sight, smell, and taste, it is, therefore, devoid of special character. Chemically pure water is, however, never met with in Nature in any serious quantity. The sanitarian, in fact, does not deal outside the laboratory with H_2O, but with $H_2O + x$. In the same way he does not deal with the characterless fluid described above, but with one which, in the great majority of cases, does possess some colour, taste, or smell, though perhaps only to a very slight degree. The possession of any such character points to the presence in the water of some substance in addition to the natural constituents, hydrogen and oxygen—to some x, in short—which may or may not be harmless, but in any case is an addition which must be identified and its character noted, in case it should be a possible cause of disease.

Circulation of Water.—All the water in the earth or in the superjacent atmosphere is in a constant state of movement in a circular direction. Starting with its condensation in the atmosphere, it falls on the earth in the form of rain, dew, snow, or hail; it then either sinks into the earth, runs over its surface, is absorbed by the vegetation, or is again evaporated into the atmosphere. The great bulk of it after a longer or shorter journey flows into the sea or the larger lakes, from the surface of which it again

evaporates, and is taken up into the atmosphere, to be once more condensed into one of the four forms already mentioned. The process may be looked upon as a gigantic and automatic system of natural purification and distribution, in which the same mass of water is perpetually furnished for the use of man, and, after pollution as a result of that use, is purified by distillation, and again supplied for fresh use. Man collects the water he needs at any point in the system of circulation that is most convenient, and it is worth keeping in mind that the farther that collection-point is removed from the original starting-point of condensation in the atmosphere, the greater is the change that will have occurred in the original, pure, characterless chemical compound, H_2O. The larger, therefore, will be the potential number of x's present, each of which may be a possible cause of disease, whose presence must, in any case, be taken into account, and its significance decided.

The Uses of Water.—Man uses water in two ways—namely, as drinking-water and as washing-water. Under drinking-water I include, of course, that used in cooking, and under washing-water that used for cleansing the body, clothing, utensils, or the surroundings of man. But to whatever use the water is put, it eventually again rejoins the great cosmical circulation. It is essential to remember this point, because if man withdraws water in any large amount from that circulation for his use, the responsibility devolves on him of facilitating its immediate return to that system. In other words, every water-supply installation demands an equivalent water-removal system. This important point has not always been kept in mind, especially in large stations in India, where excellent drinking-supplies of water have been furnished in liberal quantities, but no coincident thought taken as to its removal after use.

In whatever manner water is made use of, however, it must always be considered under six headings—viz., quantity, quality, collection, storage, distribution, and purification.

I propose, therefore, to consider water under these various headings in detail, and in doing so will follow the course of water through the circle which it follows in the air and in or on the earth, as already described.

QUANTITY.—Quantity comes to be considered logically first, since it is impossible to predicate the quality or consider the use of that whose existence has not been absolutely proved. This is one of those truisms which is so obvious that its existence is apt to be ignored. In the extreme way in which it is stated above, no sane person would think of disputing it, but the problem as it faces us in actual practice is not so baldly stated. "Quantity," in the sense in which the sanitarian uses the word when dealing with water-supply, means sufficient quantity; and it is often forgotten that no system of water-supply is a good system, no matter how excellent the quality or how perfect the arrangements for collection, storage, distribution, and, if necessary, purification, unless there is a certainty not only of the water being there, but of its always being there, and always there in sufficient quantity. Between two supplies, one of which is good in quality, but precarious in quantity, and the other plentiful, but dangerously polluted, the choice must always lie in favour of the second, no matter whether it be more difficult to collect and distribute or not. These are engineering questions that can always be solved, and even the most polluted water can be successfully purified. If the wrong choice be made and the decision given in favour of quality as against quantity, then assuredly some day the supply will fail, and the community will be driven, unprepared, to meet the engineering difficulties, and unprovided with an efficient system of purification, to fall back on the plentiful but dangerous source which it previously rejected.

Quantity of Water Necessary Daily.—The daily needs of man may be divided into personal, domestic, and municipal. For his personal use—that is, for drinking, cooking, and personal ablution, he requires about 6 gallons, which admits of the use of a sponge bath. If a large bath be indulged in, then, naturally, the amount may be as high as ten times that allowance. For domestic use—that is, for cleansing of utensils and linen, scrubbing, flushing of water-closets, etc.—it is safe to allow twice the first-named amount—say 12 gallons. For municipal demands—that is, for street-cleaning, fire-extinguishing, and so on—another 12 gallons may be allowed, making the total daily demand

about 30 gallons per head in round numbers. The amounts actually supplied in any town vary considerably in this country—from 15 and 16 gallons at Stamford (1907) and Leicester (1906) to 62½ gallons at Whitehaven (1906)—but the average allowance comes to close on the above figure. In barracks the amounts laid down by regulation are: 20 gallons a day for each man, woman, or horse; and 10 gallons a day for each child; 50 gallons a day are allowed for personnel and patients in military hospitals. The total allowance for an infantry battalion, 950 officers and men, with about 50 families, is laid down in the "Water-Supply Manual" at 30,000 gallons a day, including water for roads, and gardens, and flushing drains. Ten per cent. extra is allowed in the Service reservoirs on account of fire.

In the French Service a total of 30 litres (6½ gallons) is allowed per head, as follows: 8¾ pints for drinking, the same for cooking, for the hospital, and for general cleaning; 7 pints are allowed for ablution, and 10½ pints for laundry. A mounted man gets 5 litres (8¾ pints) more than the above. Lemoine considers this too low, and recommends an increase up to 53 litres (11½ gallons), increasing the lavatory and laundry supply. Kirchner gives the German allowance at 50 litres (nearly 11 gallons), and the Austrian at 40 litres (8 gallons 6 pints).

In tropical stations larger quantities should be allowed, principally on account of the greater amount expended on personal ablution and the washing of clothes. In practice the British officer does use very much more than that above laid down for personal use. It would undoubtedly be well if the soldier could also be supplied with enough for a satisfactory shower-bath daily. This would add 12 gallons to the present amount, and the question of removal would be a serious matter in stations where the gradient is slight.

The allowance of water on service constitutes a serious problem only in countries where water is scarce, and has to be carried—as, for instance, in the Soudan. The allowance then should be about ½ gallon as a minimum. The amount and nature of the transport available is, of course, the deciding factor.

The consideration of the quantity of water that should be allowed on the march, depending, as it does, almost entirely

on the exertions demanded of the men and the weather conditions, falls more naturally to be considered under the chapter devoted to the problems involved in "marching."

Quantity of Water derived from Rainfall.—The amount of water that can be obtained from the rainfall depends primarily on two factors—viz., the depth of the annual rainfall, and the area available for collection. This obviously gives the maximum quantity available under theoretically perfect conditions. In practice many deductions have to be made. Thus, for instance, the distribution of the rainfall in point of time is of the greatest importance. A much larger amount can be collected in stations where the seasonal rains fall continuously and heavily over a short period than in another where a large amount of total precipitation occurs, but in isolated, comparatively light, showers.

A certain amount may also have to be lost where the first washings of the collecting areas are rejected. In calculating the total area available for collection, allowance must be made for the gradient at which this is sloped. It is not the actual area, but its horizontal equivalent that is of importance. This warning is hardly necessary in the case of house-roofs, since the gradients are so steep that the precaution is less likely to be omitted. In the case of prepared areas in fortifications, where the slope is less obvious, it is occasionally apt to be forgotten. In calculating in advance the amount of rain that will be available in any station, it is usual to take the average of the three driest years on record. This lies between 70 and 80 per cent. of the average fall. Of this amount about 75 per cent. will be really available.

Quantity of Water available from the Earth.—If water is not collected as rain or dew, it must be collected after it has reached the surface of the earth. Here one of four things happen to it. It either sinks into the earth, runs over its surface, is absorbed by vegetation, or evaporated back into the air. The proportion which runs over the surface or sinks into the earth is that alone which is naturally available for purposes of water-supply. The ratios which these amounts bear to each other and to the total amount of water that actually reaches the earth's surface vary almost infinitely with the local meteorological, botanical, and

geological conditions. According to Woodward ("Geology of Water-Supply," p. 52), the amount of water that percolates in Britain averages from one-quarter to one-fifth of the rainfall, whilst the "surface run-off" is about one-sixth. Vegetation and evaporation from the surface account for the remaining two-fifths. No such rules can be held to apply to any place but that in which they are formulated. In any new station, if accurate calculations are required, then accurate observations must be made. Ordinarily, however, it is possible to arrive at a reasonable estimate after a careful study of the local conditions.

The water that runs off over the surface forms streams, rivers, ponds, or lakes, and these are obvious sources of water-supply, providing quantities proportionate to their size, and in the case of moving waters, streams, or rivers, to the rapidity of their flow as well. It is unlikely that the medical officer will ever be asked to give more than a rough estimate of the yield of such sources of supply, and for this purpose the methods described in the "Field-Service Pocket-Book" are sufficient. Accurate calculations would devolve naturally on the Royal Engineer officer concerned. Dealing, then, purely with quantity, it is unnecessary to dilate farther on the water derived from "surface run-off." That water which percolates into the earth now demands attention. This water sinks into the earth until it reaches a stratum of rock that imposes an impermeable, or relatively impermeable, barrier to its farther progress. When this occurs, the water in question spreads laterally in the line of least resistance, and forms what is called the "ground-water," or, when very close to the surface, the "sub-soil water." This may occur at any distance from the surface, depending solely on the depth of the first impervious, or so-called impervious, layer. At the same time, since no rock is absolutely impervious, and every rock, however impervious in texture, is liable to fissuring and other breaches of continuity, water can descend to even greater depths, and at any one point on the surface. If we descend vertically, we shall find several layers of ground water, each lying in a pervious and on an impervious stratum of rock.

A "water-bearing"' stratum is one which, being itself

pervious, allows of the free passage of water in any direction through its substance, the farther downward movement of the fluid being obstructed by some subjacent, comparatively impervious, rock. The mere power of retaining water does not make a stratum water-bearing. If this property is due to the intimate structure of the rock, as in the case of the London Clay, then the "water-bearing" capacity is in inverse ratio to its "water-holding" power. The water-holding power of a water-bearing rock is conferred on it by the presence of the impervious layer below, and is not the result of its own intimate structure.

In the more superficial strata it is probable that the ground or subsoil water forms a more or less continuous subterranean sheet, but the deeper we descend the more likely it is that we shall find this continuous sheet broken up into discrete lagoons, or even well-defined river-beds whose direction may in no way agree with the lines of the surface drainage.

The quantity of water held in any water-bearing stratum will depend on four factors. Firstly, of course, on the amount of rainfall; secondly, on the amount actually percolating to the depth under consideration; thirdly, on the slope or "dip" of the impervious stratum; and fourthly, on the retaining power of the water-bearing stratum. It is obvious that, comparing different water-bearing strata in the same conditions as regards locality, the two last-named factors are of paramount importance. The water having penetrated as far as the "impervious" stratum, will flow more quickly downwards if that stratum lies at a steep dip, or if the water-bearing rock possesses a high degree of permeability; on the other hand, it will accumulate to a greater depth if the "impervious" stratum is horizontal, or nearly so, or the water-bearing layer is of a comparatively retentive character.

The quantity of water that can be procured from any stratum will, naturally depend on the quantity retained, and this naturally varies with the character of the various water-bearing rocks. But it also depends on the freedom with which the water-bearing stratum will part with its water. The net result—*i.e.*, the water-supply—is therefore the product of many factors. For instance, a loose sand

lying on a horizontal bed of clay will yield a copious supply of water, since it itself imposes just enough resistance to the flow of the ground-water to oppose its escape in a lateral direction, but yet not enough to impede its collection by mechanical means—*e.g.*, pumping. On the other hand, a stiff clay—*e.g.*, china clay—may hold as much as 70 per cent. of its bulk of water, owing to the great, though not absolute, resistance that its texture imposes to the passage of the fluid. At the same time this resistance prevents any large supply of water being drawn from the mass present, since it impedes the movement necessary to fill a well or supply a pump. It is impossible in a work of the dimensions of the present one to discuss fully the many relations of the underground water. For such the reader is referred to Woodward's "Geology of Water-Supply," which enters into considerable details on these points, and is an invaluable handbook to any officer specially engaged in water-supply work.

Springs and Wells.—If the surface of the ground be sloped at an angle steeper than that at which the impermeable stratum "dips," then it is obvious that the underground water, flowing through the water-bearing stratum which lies on the impervious one, will eventually appear at the surface either as a spring, or a line of springs, or as a diffuse oozing that goes by the descriptive name of "seepage." Various other causes conduce to the formation of springs, but in all the same principle is present. The water comes to the surface, and is there available for the use of man, as the result of the action of gravity acting against and along certain planes or lines of resistance. If the underground water does not *come* to the surface, then man digs a well, which passes down to the water-bearing stratum, and by purely mechanical means—pumping, etc.—*fetches* it to the surface. Except for the fact that in the one case the means are what we call "natural," and in the other "artificial," there is no difference in the supply provided by a spring or a well. The quantity to be obtained from a spring or from a well varies, however, in the following manner, supposing the permeability of the water-bearing stratum to be the same in both cases: In the spring the delivery is proportionate to a *vis a tergo*—to the pressure—

that is, the depth of water in the water-bearing stratum. In the well the delivery is due to a *vis a fronte*—the suction of the pump that drags the water to the surface.

Regularity of Supply from Springs and Wells.—The regularity of supply from a spring or well will depend on the distance which the water has had to traverse subterraneously, or the resistance which it has had to overcome from the time when it first struck the surface of the earth to the time at which it is placed naturally or artificially at the disposal of man. It is easily comprehensible that if the water which falls as rain has only a few feet of earth to pass through before it reaches a well or spring, that well or spring will vary closely in its output with the daily or weekly supply of rain. The greater the distance which has to be traversed, the less close will be the connection, till after a certain time neither well nor spring is influenced by daily, monthly, or even annual variations in the local rainfall. This distance need not necessarily be vertical—in fact, it is immaterial in what direction the water has travelled. All that is necessary is that the resistance imposed should have been sufficient to "tail out," so to speak, the various detachments of water, representing the various showers of rain, on their passage through the ground, so that the originally existing distinctions imposed by difference in original date shall be gradually smoothed out, and the intermittent downfall of rain transformed into the steady output of the permanent spring or the reliable well.

Wells differ from springs as sources of supply in one very important manner. Since the delivery of a well depends very largely on the *vis a fronte* imposed by the action of pumping, any great variation in that demand —especially, of course, in the direction of an increase—may cause a serious disturbance in the water-bearing stratum, and therefore a marked alteration in the amount provided. Supposing a well, for instance, to be pumped for ten hours a day continuously, and to deliver 100,000 gallons a day with absolute regularity over a long period. This fact gives us no guarantee that twenty hours' pumping will yield 200,000 gallons a day. Such a disturbance may open up new sources of supply, or may temporarily

exhaust, or even close, existing sources. Another fallacy has to be guarded against. I have known it suggested in the case of a failing supply that more wells should be dug. Such a resort may succeed if the scantiness of the output is due to deficient means of collection in the presence of an ample subterranean supply. If the deficiency be due (as in a case which I have in my mind, in which such a suggestion was made) to a failing underground reservoir, then it is as futile to hope to increase your supply by adding to the number of your wells as it would be for a man to increase his income by multiplying the number of his cheque-books. In either case he will be merely increasing the draft on a slowly waning balance, and the result will as surely be a water famine in the one case as it will be bankruptcy in the other.

Artesian Wells.—These are wells in which the water rises to the surface, or even overflows, as a result of subterranean hydrostatic pressure. They are, in fact, not so much wells as springs, to which an artificial outlet has been provided. A typical instance of their formation may be noted in the London Basin. Here we have a water-bearing stratum, the Chalk, lying on the impervious Gault Clay, and dipping under the London Clay. Rain falling on the Chalk hills that encircle London sinks down through the pervious Chalk, and is held up in a natural basin by the underlying Gault. A bore driven down through the London Clay gives an outlet to the pent-up supply, which is forced to the surface by its own hydrostatic pressure, since the water-level in the Chalk is higher than the level at which London stands. Artesian wells give supplies which are extremely constant as regards quantity, and from their nature are, after the primary cost of boring, cheap in the matter of working expenses. It is dangerous, however, to suppose that because a copious supply has been procured from one artesian well we can count firmly on duplicating the supply from other borings. The water that is delivered from artesian wells is held chiefly in fissures, and later borings may fail to hit off satisfactory reservoirs, or may interfere with previously successful wells.

Quality.—The quality of a water depends on the matters added to the water subsequently to its condensation in

the atmosphere up till the time at which it is taken by man for his use. These substances are taken up from the air or the earth, and their real significance, from the point of view of the sanitarian, is that they furnish a record of the path taken by the water under consideration during the time that has elapsed since its first condensation. From this he is able to calculate whether it has undergone any risk of being contaminated by the actual causes of disease.

Quality of Rain-Water.—The first additions to the water are the various gases existing normally in the atmosphere which are taken up by it in solution. In the neighbourhood of manufacturing towns various other gases may be absorbed, but from the point of view of the sanitarian these are of the less importance, since rain-water is not collected for drinking purposes in the neighbourhood of such localities. The most important of the gases that are taken up by the falling rain is carbonic acid, on account of the solvent action which it exercises on the alkaline carbonates. In addition to these gases, the rain takes up in suspension floating particles of dust, etc., and a certain number of bacteria. It is extremely doubtful, however, if these particles, even when they happen to be specific micro-organisms, have any sensible effect on the water in the direction of causing disease. I should feel inclined to hold that up to the moment at which the rain touches the prepared collecting surface the additions which have been made to the water are small in amount, and negligible as regards importance. The serious additions are furnished not by the air through which the rain passes, but from the surface on which it falls. It is obvious that in the period that elapses between showers the collecting surface, whether it be a roof or a prepared area in a fortification, is open to contamination by débris, animal or vegetable in their origin—*e.g.*, bird droppings—and by wind-borne particles of all possible descriptions. This is so obvious that where roof-collected rain-water is used for purposes of supply it is usual to reject automatically the first washings off the roof.

In Gibraltar and Bermuda the entire water-supply of the garrison is procured from rainfall, collected either on roofs

or on prepared areas. In the former station the water contains large numbers of *Bacillus coli*, this micro-organism being present often in samples as small as 1 c.c., and almost invariably in 10 c.c. The supply in Bermuda also contains large numbers of organisms which appear to be related to the *Coli* group, though of an aberrant type. In neither of these stations, however, have any outbreaks of disease been traced to the water-supply, and it is certain that standards of purity suitable for localities where the water is derived from subterranean or surface sources cannot be held applicable to rain-water supplies. Naturally, collecting areas must not be placed in close proximity to sewage-disposal works or filth trenching-grounds. Unless so placed, there is no evidence at present that the additions made to the water at this stage have any definite sanitary significance.

Quality of Ground-Water.—The water which sinks into the earth at once begins to take up substances in suspension and solution. Of those which it dissolves some are taken up by the inherent solvent power of water, others by the action of the carbonic acid previously absorbed from the atmosphere or from the soil itself. These last are the alkaline carbonates, of which the most important is carbonate of lime. These salts render the water "hard," but since their presence depends only on the solvent power of the predissolved carbonic acid, the hardness they produce is commonly called "temporary hardness." Any agent which drives off or is able to combine with this carbonic acid, will immediately rob the water of its alkaline carbonates, and thus remove the "temporary hardness" which they produce. The farther the water sinks through the earth the greater the amount of substances it will dissolve, and these, which are not held in solution by the presence of the carbonic acid, constitute the "permanent hardness." The most important are the sulphates of lime and magnesia, but different rocks give up different substances, some of which, as in the case of the saline springs, materially affect the taste of the water, and confer on it various medicinal properties. It is very doubtful whether the carbonates and sulphates which produce temporary and permanent hardness have any serious effect in the

direction of disease production. Individuals moving suddenly from a "soft" water to a "hard" water district are apt at first to suffer from constipation and other digestive disturbance, or in some cases from rheumatic symptoms; but in the majority of cases these effects are purely temporary.

The chief significance of "hardness" is economic. Such waters cause a great destruction of soap, owing to the formation of insoluble oleates, and from this cause alone it was calculated that the city of Glasgow saved £30,000 a year after the introduction of the Loch Katrine water. A considerable waste of fuel also results from the formation of a thick fur deposited on the inner surfaces of kettles and boilers, and also owing to the fact that meat and vegetables have to be boiled for longer periods in a hard than in a soft water. On the other hand, hard waters are preferred for certain trades—*e.g.*, brewing—as exemplified by the well-known hard water of Burton-on-Trent. Goitre has been attributed to the presence of certain dissolved mineral matters in water, but this disease occurs under so many different combinations of conditions that it has not yet been found possible to identify any one factor common to all. After the salts which produce hardness, the most important of all matters taken up by the water in its passage through the earth is chloride of sodium. This substance does not of itself possess any importance. It causes no disease, even when present in quantities sufficiently large to affect the taste, and therefore the potability, of the water. The significance of this salt lies in the fact that, being a constant ingredient of urine, and therefore of sewage, its presence in water may point to the conclusion that at some time or other that water was contaminated by sewage, and therefore potentially by disease germs. But here, again, it is important to note that the mere presence of the salt is of no value as evidence of contamination. All waters practically contain some chloride of sodium; some of them contain even considerable quantities, derived purely from mineral sources, and therefore absolutely devoid of significance from a sanitary point of view. The important point to ascertain is, first, the normal chloride content of the water. If this remains

unchanged, then there is no danger to be apprehended, but any marked increase is a warning whose meaning must be elucidated. The usual limit laid down is about 4 parts per 100,000, but such a rule has no validity. Three parts per 100,000 in a water whose normal content was one part would mean danger, whereas seven parts would possess no importance if this represented the usual proportion found by analysis. An excess of chlorine is found in certain geological formations—*e.g.*, the Permian—also in wells near the sea, or in surface-waters in districts exposed to constant strong sea-winds—*e.g.*, Cornwall.

It should be noted by the military sanitary officer that the chlorine figure is almost invariably high in the well-waters of Upper India.

In addition to these purely mineral matters, the water in its passage through the earth takes up in solution certain nitrogenous compounds which are entirely of organic origin, and due to the decomposition of organic matter, animal or vegetable, lying on or underneath the surface. The importance of these substances lies in the fact that they not only point to pollution by organic matter, which may possibly be of animal, and therefore, possibly, also of human, origin, but that by the stage of oxidation to which the nitrogen has advanced they also give some clue to the length of time that has elapsed since the organic matter was originally deposited in or on the earth. One of the earliest products of decomposition of organic nitrogenous material is ammonia, which, by process of oxidation, is converted first into nitrous acid, and later into nitric acid, these last being found in the water as nitrites and nitrates respectively. These substances are derived invariably, it may be said, from organic matter originally. On the other hand, all waters contain a certain amount of ammonia, which may be derived even from the air, and the presence of free ammonia, therefore, in small amounts is not considered of serious importance. The presence of large amounts of ammonia, or of even small quantities of nitrites, is held, however, to point distinctly to organic contamination having occurred at no very distant date. Nitrates represent the ultimate stage of oxidation, and therefore do not possess the same significance, since they

may originate from organic matter of geologic date. Nitrates may be reduced again to nitrites, but in shallow well-waters this is rare, if, indeed, it ever occurs.

The evidence offered by the presence of these nitrogenous compounds is, therefore, of very great value if properly weighed. Two points only must be kept in mind in estimating the value of that evidence. The first is that the significance of the fact that ammonia, nitrites, or nitrates are present in the water consists in their pointing to contamination by organic matter, which may be, first, possibly of animal origin ; secondly, possibly fæcal ; thirdly, possibly human ; and, lastly, may possibly contain the germs of some water-borne disease. The chain is neither short nor direct, and conclusions which would be quite justifiable under conditions such as we are accustomed to in these islands might be extremely unsound in countries where the soil and climate differ very materially from those of Great Britain. The experience of many years has shown that in this country it is safe to connect certain facts at one end of that chain with certain conclusions at the other. That experience is not sufficient to enable us to say that, under all conditions and in all circumstances, the same line of argument will hold. Dealing, as we, the medical officers of the army, often have to do, with conditions which are strange to us, it is necessary to reopen, as it were, the case at every fresh station at which we serve. The second point to be remembered is that these matters are in themselves innocuous. They are not dangers, but only danger-signals.

Amongst the organic substances taken up from vegetable matter must be mentioned humic acid. This is present in a large number of moorland waters, and where these come into contact with lead, whether in the form of lead ore in the earth or lead piping in the system of distribution, they are apt to dissolve a sufficient amount of that metal to cause poisonous symptoms. Numerous cases of lead-poisoning have been traced to this cause in the North of England ; in Northumberland a great deal of the underground water is rendered unfit for use in consequence. A similar action takes place in the case of zinc, and an upland water may dissolve this metal from gal-

vanized iron pipes or cisterns, especially when these are new. In the case of a new installation at the Cordite Factory in the Nilgiri Hills zinc was present in the water delivered to the factory to the extent of 1 part per 100,000, but has now, after a lapse of five years, disappeared. No bad effects were experienced by the people who consumed this water, though the metal persisted for at least two years.

In addition to the substances which it dissolves, the water also takes up certain matters in suspension. Just, however, as the amount of dissolved matters increases with the distance through which the water has percolated through the earth, so that of suspended matters diminishes. The earth, in fact, acts as a very efficient form of filter. Suspended matters may be divided into animate and inanimate. The latter are of little importance, as a rule, unless present in such quantities as to render the water obviously turbid. In the case of surface supplies or shallow wells it is possible, especially under service conditions, that the water may contain such matter in quantity sufficient to act as a direct mechanical irritant to the mucous membrane of the alimentary canal. In India fine particles of mica are sometimes found in the waters of the Himalayan hill-stations, and have been accused of causing that troublesome disease, hill diarrhœa. This can hardly be held to be proven as yet. Perhaps some cases have this etiology, but many are undoubtedly of microbial origin, and related closely to sprue. In the South African War the suspended matters in the water of some rivers were accused of causing diarrhœa. Other suspended matters are those which originate from human clothing, such as fibres of linen, wool, or cotton, or from the human body, such as scales of epithelium or hairs. The significance of these lies, of course, in the fact that they point to the possibility of contamination by human excreta, either directly or as a result of the washing of soiled clothing.

By far the most important of the suspended matters belong, however, to the animate class. This class includes the various entozoa, and also, and most importantly, various micro-organisms. These belong to two classes—(1) those which actually cause disease, and (2) the micro-

organisms which constitute the normal flora of the human intestine which constantly accompany those pathogenic germs. The entozoa need not detain us.

The micro-organisms which actually cause disease are those of cholera, enteric fever, and dysentery, and their constant concomitants are the *Bacillus coli* in the first place, and less importantly the streptococci, and the *B. enteritidis sporogenes*. I need hardly say that the presence of even a single disease-producing microbe in a water sample would suffice to condemn the source at once. In the case of cholera the specific spirillum can be isolated and identified in water with comparative ease. In the case of enteric fever this is, however, not the case. It is, in my opinion, doubtful whether this micro-organism has ever been isolated from a natural water to which it had not been purposely added. In the earlier days of bacteriological research I am aware that this discovery was reported with considerable frequency, but the evidence which was then considered sufficiently strong to decide the question in the affirmative would not be accepted nowadays. The present practice is to limit the search for micro-organisms to the *B. coli* almost exclusively. The presence of this bacillus in any great numbers would, if supported by the results of a chemical examination and of an examination of the source from which the water was drawn, justify us in condemning the water for use. Here, again, as in the case of chlorine and nitrogenous compounds, we are relying not on the actual discovery of the cause of disease, but on the presence of a certain substance in the water, which must inevitably be there if the disease cause exists in the source. The exact number of germs of this species which would justify us in condemning a water cannot be laid down with any certainty. The surroundings must be taken into consideration, and the evidence from all sides carefully balanced. It is not so usual at the present day to search for streptococci and for *B. enteritidis sporogenes*, as used to be the case some few years ago. Their presence would certainly not weigh against the evidence furnished by the non-discovery of *B. coli*, though this result might cause grave doubts as to the skill of the analyst. On the other hand, a positive result obtained in an examination directed to discovering this

last-named micro-organism would be neither strengthened nor weakened by the presence or the absence of the other two.

If we consider the impurities which water takes up from the air and the earth in its passage through these media, we see that, whilst the alkaline carbonates may in special instances cause dyspepsia or rheumatism, and the acids present in the softer waters may accidentally be the origin of lead-poisoning, the only true disease causes added to the water are the eggs of certain entozoa and the micro-organisms of the water-borne diseases.

All examinations intended to decide the quality of a water are directed to ascertaining this last point, but in doing so we are guided, as regards chemical and bacterial examinations, by the presence or absence of certain other additions or impurities which are not in themselves pathogenic, but which, since they must be present if the disease cause is present, act as danger signals, showing the possibility at least of pollution. It must be remembered that we can only say of these matters that they must be present if the disease cause is present, not, as it would seem, from the use made of such evidence by some that the disease cause must be present because they are present. Our deductions, then, can only be looked on as not unjustifiable inferences, by no means as certain, logically proved facts.

This brings us to the very important question of the methods to be adopted for the purpose of ascertaining the quality of a water. There are three of these at our disposal : (1) An inspection of the source from which the water is derived and its surroundings ; (2) a chemical, and (3) a bacteriological examination of certain small samples of the water itself. If it is desired to give a complete report on any water, all three methods must be made use of ; but if any one is to be dispensed with, then it must be one of the last two. The first method, primitive though it may seem, is absolutely essential. It is worth while to consider shortly the nature of the evidence furnished by these different methods of examination. By the first we can learn all the possibilities that exist for contamination of the water ; we may even be able to say definitely that such and such a definite contamination has occurred. If

contamination be present, we can decide whether it is casual or of a permanent, unavoidable nature, and in the former case, whether any measures of prevention are likely to be successful, and, if so, what such measures should be. We can also decide whether the contamination is due to human or only to animal excreta. In the case of the bacteriological and chemical examinations we can only say that in a certain small amount of water—say half a gallon—we have found, or failed to find, certain chemical substances or certain micro-organisms which would certainly be present if fæcal contamination had occurred. We can also lay down roughly the probable date of the contamination. We can give no opinion as to the actual nature of the contamination, whether human or animal. In the case of the chemical examination it is not always possible even to distinguish clearly between animal and vegetable, and we can draw no deductions as to whether the contamination is due to some inevitable condition, or merely to some passing accident. Repeated examinations continued over a long period furnish, naturally, somewhat stronger evidence ; but a true interpretation of the results obtained can only be derived from an actual inspection of the source. Two instances that I have met with during the course of my service illustrate this point so clearly that I venture to give them at length. In the first the water, which issued from a large spring at the foot of the hills near Chaman, on the Afghan frontier, was found to be chemically and bacteriologically as free from contamination as any water could well be. Ammonia and oxidizable matters were almost absent, and the chlorine figure was low. There were only one or two micro-organisms in each cubic centimetre, and none of the intestinal group were found. On inspection of the source, it was found that a native cemetery was situated within 20 yards of the mouth of the spring, and almost exactly above it. There had been, so I was informed, no burial in the cemetery for many years ; but, by a strange coincidence, one was actually in progress at the time of my visit. The soil was hard and impermeable, though liable to fissures. The temperature was not much above freezing-point in the day, and close to zero at night. It so happened that no

fissure had developed opening up communication between one of the numerous graves on the hillside and the underground channel of the water. At the same time such a rift might at any moment develop, and, naturally, the source was condemned. In the second case the water showed abundant signs chemically of gross organic contamination, and swarmed with *B. coli*. An inspection of the source showed that the organic matter was largely vegetable in its origin, whilst the fæcal contamination which the result of the bacteriological examination pointed to was due to the excreta of cattle and sheep. In the first case the source could not well be protected, whilst in the second the provision of a few hundred yards of wire fencing would safeguard the supply with absolute certainty. Chemical and bacteriological examinations, when they give positive results, draw attention, it is true, to conditions which might in their absence escape notice. They are, of course, also useful aids in the administration of a water-supply system, once that has been established. For open sources of supply —and it is with these that on service we mostly have to deal—they are by themselves most misleading. Negative results are, of course, absolutely valueless. A great deal of nonsense has, in my opinion, been talked about this point of water examination on service. With fighting troops it is unnecessary, since all water is *ipso facto* contaminated if it come from open sources in a district which is the scene of hostilities. It may be urged that this statement can hardly hold good in the case of previously uninhabited, or only sparsely inhabited, countries, such as our troops frequently have to campaign in. A district may be absolutely uninhabited prior to the arrival of an army, but once that has taken place, it is obviously not only inhabited, but, in the immediate vicinity of the force, densely inhabited. The sanitary officer who, on the strength of negative results obtained from a chemical or bacteriological examination, permitted neglect of the usual methods of purification would make a serious mistake. I repeat, then, that it may be accepted as an axiom that on service all open sources of water are *ipso facto* contaminated, and therefore all equally demand purification.

The quantity and quality of the water available having

been determined, it is necessary to consider next its collection, storage, and distribution, in the order named. Purification comes in, of course, at some period in the series, but will be considered most conveniently last of all. It may be intercalated immediately after collection, in which case the processes of storage and distribution must be so conducted as not in any way to undo the work of the previous process of purification. In any case, of course, it is important that the quality of the water should not deteriorate during these processes, and, also, that there should be no waste.

Collection. — Water may be collected as rain-water immediately after it reaches the surface of the ground, on specially prepared areas, or on roofs. As already stated, such prepared areas are apt to be exposed to more or less wind-borne contamination, from which it is impossible to protect them. Prepared areas in fortifications and elsewhere should be protected by means of barbed-wire fencing from any casual trespass by men or animals. In fortifications it is the custom to paint these areas in squares of different colours, so as to render them less conspicuous, and thus avoid attracting hostile fire. It is important that the pigments used should contain no lead or chromium, which might be taken up by the water. Apart from the above measures, but little is necessary or feasible. Where water is collected from roofs, it is usual to reject the first flow, which performs the function of washing the roof. This is done by means of a mechanical contrivance called a "Roberts rain-water separator." In this the first flow is directed to waste, with the exception of a small portion which collects in a canting chamber. When this chamber is full, it tips over, operating a lever which directs the subsequent flow to the storage reservoir. Purification of rain-water by filtration should always be carried out, in view of the inevitability of contamination, which may on occasion, though not, I believe, frequently, be of a dangerous character.

Collection of Ground-Water.—Ground-water is collected either from springs or wells. In the former case not much need be said. The flow of the spring is impounded in a reservoir, and then distributed. In the case of a well, a

few remarks are necessary. In the first place, it must be remembered that when a well is sunk to a certain depth, it is with a view to getting water from that depth. No other water should be allowed to enter the well. This is effected by giving the well an impervious lining, consisting either of a metal tube or of brickwork, bedded in cement, and lined with hydraulic cement. In comparatively loose soils, the brickwork should be puddled at the back with clay. This precaution will prevent water coming from the upper layers of the soil or rock. To prevent surface washings obtaining access to the well, a substantial masonry curb should be built round the edge of the well, and to prevent rain-water or air-borne contamination getting in, the well must be covered over. Both these objects may be attained by hermetically sealing up the well and covering this over with earth. The exact nature of the materials used for this protection and the manner in which those materials are used is a question of detail. In some form or another these three separate possible avenues should be protected against the entrance of casual contamination. When a well is pumped, the level of the water in the well and in the water-bearing stratum in the immediate vicinity of the well is lowered. This depression becomes gradually less and less till at a certain distance the demand made on the well has no particular effect on the subsoil water-level. The line of water saturation within the area affected by the well is, therefore, no longer level, but slopes gradually upward and outward from the water-level maintained in the well. In this way an inverted cone is formed, the size of which depends on two factors—viz., the *vis a fronte* of the pumping operations and the amount of resistance opposed to the flow of the water by the peculiar structure of the water-bearing stratum. The looser the soil and the greater the demand, the wider will be the cone of depression ; whilst with a dense rock and a small demand the cone will be correspondingly narrowed. If the rate of demand on the well be constant, and the rocks do not contain a large proportion of minerals readily soluble in water, the cone of depression will remain constant once the well has got established. A sudden increase in the demand, or the formation of a rift or hole in the rock, the result of solution

of certain of its component minerals, will, of course, alter the dimensions and arrangement of the cone. The importance of this lies in the facts to which allusion has already been made. As long as the demand is constant, and the structure of the rock or soil undisturbed, so long it may be anticipated that the quantity and the quality of the water available will also remain unchanged. Given, however, any such sudden alteration in the demand or the structure of the rock as I have just mentioned, it will be necessary to await the collection of new data, as regards both quality and quantity, before any permanent reliance can be placed on the well under its new regimen.

Wells are divided into deep wells and shallow wells, and it is usual to lay down some definite standard of depth which divides the one class from the other. This is apt to be misleading. The real depth of a well is not the distance measured vertically from the surface of the earth to the well-bottom, but the distance which the water has had to travel through the earth from the spot on which it first fell to the position in which it is found available for use. It is probable that any well that is 100 feet or more in vertical depth may be classed as a deep well, since the vertical distance in itself represents a mass of soil sufficient to deprive the water of any casual impurities by a mere filtration. On the other hand, if this depth be measured through a homogeneous soil, it is possible that a fissure or a series of fissures may communicate between the surface and the subsoil water, and thus rob the well of its apparent advantage. A truer definition, in my mind, of a deep well is one that penetrates through two impervious layers of soil or rock. Such a well, even if only 20 feet deep, possesses the advantage that the water that appears at the bottom must have travelled through a long and circuitous route from the spot at which it first fell. If there be only one impervious layer, then it is possible for a fissure to develop close to the well, and cause a direct communication with the surface. With two impervious layers, it is unlikely that two fissures, one in each layer, shall develop exactly opposite each other, and afford such direct communication. Naturally, the deeper a well, measured vertically, the better, other things being equal ; but it must be constantly

remembered that an apparently shallow well may, when the geological situation has been ascertained, turn out to possess in reality, and to a far greater degree, the essential qualities of a deep well—that is, regularity of output and constancy of quality—than another well which the superficial observer might class as "deep."

Water may be collected from that portion of the rainfall which runs off the surface, and is then in general impounded in artificial reservoirs. This is done in the case of certain stations in India—*e.g.*, Bangalore and Secunderabad. In the former case a large lake is formed, some eight miles in length, and averaging three-quarters of a mile in breadth. The questions involved in the construction of such reservoirs are largely of an engineering nature, but the sanitary officer may be asked to advise on the question of what margin of land should be taken up round the edge of the lake with a view to safeguarding the water against pollution. This is a question in which pecuniary considerations of considerable magnitude are involved, and it is important to take up a reasonable attitude on the subject. The first point to be considered is the size of the lake and the daily demand made upon it. Where the latter is trifling compared with the former, it is obvious that the time occupied in the passage of any particular contamination from the farthest extremity of the lake to the outlet must be extremely long, and at any intermediate spot directly proportional to the distance from the outlet. Knowing, as we do now, the important purifying effect of sedimentation, and the fact that specific micro-organisms of disease are not favourably placed when exposed to sunlight, and the competition of the hardier vegetative germs, it is obvious that in a long lake such as that just mentioned, the contamination due to the presence of a village at the end of the lake farthest from the outlet is practically negligible, and the danger attributable to any other source of pollution is inversely proportional to its distance from the outlet. In the immediate vicinity of the outlet, naturally, stringent steps must be taken, especially in respect of small gullies running down into the lake, which are liable to be used as latrines by the natives. Every such case must be judged on its own merits, and no hard-and-fast line can be drawn.

The sanitary officer, in dealing with a scheme of this nature, must remember that he is not called on to aim at an ideally perfect reservoir, absolutely and certainly free from the remotest possibility of contamination. Reasonable security is all that can be demanded, and such a degree of security is all that Government is prepared to pay for. Storage is necessary in all cases where the supply is intermittent. In the case of rain-water—as, for instance, in Gibraltar—cisterns are provided sufficient to hold a supply for a prolonged period of drought. These are closed in, and such cisterns, surrounded as they are by dwellings, must inevitably be so. The disadvantage of this is that it is impossible to see what is happening. Pollution may occur during storage in such cisterns, owing to surface-washings finding entrance through manholes, or through cracks in the walls of the cistern, the result of settlement. The reports from Gibraltar (A.M.D. Reports, *passim*) touch frequently on these difficulties. From what has been said under the head of "Collection," it will be readily understood that in the case of a rain-water supply pollution is practically inevitable, on account of the difficulties attaching to collection and storage. An installation of Berkefeld candles was recommended in the Report for 1908, and is gradually being introduced at this station.

Storage is also necessary in cases where a piped supply of water is in use, whether derived originally from wells or from natural or artificial lakes. This is done in what are called "service reservoirs," holding from one to three days' supply, situated in the immediate vicinity of the station. These permit of any sudden demand being met—*e.g.*, in the case of fire—and also prevent interruption of the service as a result of injury to the pipe-line. It is usual to roof these over, but I have never been able to convince myself of the necessity or even advisability of this step, especially in India, or any other tropical station. Wind-blown contamination must, of course, be guarded against, but this can best be done by wise choice of position. In any case, it is almost impossible to prevent such contamination through the ventilators that are always provided. I have a vivid recollection of seeing the surface of the water in the roofed-in service reservoirs at Quetta

covered with the floating bodies of dead locusts, which had penetrated through the ventilators. If foreign bodies of such size can penetrate into a reservoir, it is obvious that mere roofing will not keep out contamination by particles of infected dust, etc. If contamination is inevitable to some degree, then it is, in my opinion, infinitely preferable to arrange so that one shall be able to see it. I should be sceptical of the danger from such casual contamination to which an open-service reservoir would be exposed under an Indian sun.

Storage is sometimes provided for by cisterns in barracks, though it is intended that these should be reduced to a minimum. There has been a good deal of, in my opinion, unnecessary prejudice against such distribution cisterns. A direct supply from the main is theoretically excellent, but in practice it means a great deal of inconvenience. The defects in cisterns lie, not in the apparatus, but in the individuals who design their position in the house. It seems a rule that the water cistern should be placed in some out-of-the-way, dark corner, as if it came into the *catena rerum tacendarum*. This is not at all necessary. A cistern placed where it can be easily inspected and, if necessary, cleaned out, is a most useful appliance, and need not in any way interfere with the sanitation of the dwelling. In India it is usual to supply galvanized-iron tubs for the storage of water in bungalow verandas. These are a necessity where stand-pipes are situated at a distance from the bungalows. Great care should be taken to see that they are periodically scoured and placed on the cool side of the building.

Distribution in Barracks.—This presents no peculiar difficulties in military stations at home, or where water is laid on direct to the different barrack buildings. In such cases the soldier has merely to go to the nearest tap to procure a drink, or to fill his water-bottle, and the responsibility for the cleanliness of that receptacle or of the mug he uses rests on him alone. In a considerable number of stations, more especially in India, this is not the case, and the water has to be collected from a few stand-pipes scattered throughout barracks, and conveyed from those points to the various isolated bungalows, and there stored in small cisterns in the verandas, in the manner already

referred to. The question is complicated when, as is not infrequently the case, it is considered necessary to submit the water to some preliminary process of purification by boiling before actual distribution to the barrack bungalows. The conditions, in fact, approximate somewhat to those met with on field service, and the problem should be tackled in much the same way. In fact, great though the disadvantages of any system such as I have just sketched undoubtedly are, still, they may be turned to good account if the opportunity is taken of training the men in the regular observance of a methodical ritual of distribution. The essence of this ritual lies in the principle that water should be distributed by certain people only, and at certain times only. The carrying out of this ritual should be entrusted to responsible individuals who recognize the importance of the task, not to natives of the country, even though water-carrying may be their hereditary profession. I am quite aware of the difficulties attendant on such a process. The weight of the drinking-water required by a company 100 strong, allowing half a gallon to each man—no excessive allowance on a hot day in India—is 500 pounds; for a whole battalion, therefore, close on two tons. System or no system, this has somehow to be transported from the stand-pipes to the bungalows, and it seems to me that the absence of a system is little likely to render the solution of the problem any the easier. Where boiling is resorted to as a method of purification, this transport performance has to be repeated twice over, and the need of method is, of course, thereby doubled. It has often seemed to me that the fact of the water being boiled at some stage on its journey from the stand-pipe to the barracks was looked on as conferring some magical safeguard on the fluid, destroying not only any pollution antecedent to the process, but also extending, as it were, the ægis of its protection over the water during its subsequent wanderings. It is immaterial what the system adopted is in actual detail, but I would like to suggest certain points which seem to me essential if the method adopted is to be successful. In the first place, the entire process should be placed under the supervision of a non-commissioned officer—if possible, a lance-sergeant. He must not be too young, or he will lack

authority and knowledge ; nor too senior, or he will lack incentive to work. The same man should not be kept at the work too long—a month or two at the outside would be sufficient. In this manner a considerable number of senior sergeants will have been through the mill, and learnt the importance of the subject. This will be of the very greatest value in time of war. Under this man should be a certain number of privates—say two per company—forming the water party. Any actual handling of the water should be done by these men, and not by natives. The latter may carry the buckets or drag the cart in which the water is transported to its destination ; but they must on no account be allowed to manipulate taps or do any other thing which necessarily brings any portion of their bodies into contact with the water itself. Lastly, there should be a definite time for water distribution—preferably, of course, the early hours of the morning. If the water has to be boiled, the same men must supervise this process, and the subsequent details of cooling, etc. If this system seems too complicated, then I would advise that the companies be marched to the nearest stand-pipe and the men made to fill their water-bottles, after morning parade, and again, if necessary, in the evening. In such a case boiling may be dispensed with. This, again, would have an educational effect of the greatest value, as assisting to inculcate restraint in drinking.

It is the duty of every medical officer in charge of effective troops in a station such as I have been referring to to impress on the officer commanding those troops, as strongly as he can, the enormous importance of attending to the smallest details of water-distribution, whether in barracks or in the field. A battalion that has been drilled in this respect in cantonments will have the greatest possible advantage as compared with another battalion coming from some station where a proper piped supply was laid on into barracks, and the soldier, finding everything done for him, did not realize the necessity of doing something for himself. In the field, of course, the chances of contamination are multiplied a thousandfold, and care and system are, therefore, all the more important. If the habit has been learnt in peace, there is at least hope that it will be practised in war. If it has been neglected, or has been unnecessary in

cantonments, it will certainly be neglected in the first case, and be much harder to learn in the second, when the battalion is on service. This care and system, which are very properly grouped together under the term "water discipline," constitute one of the most important means of keeping the ranks full in war ; and there should be no more difficulty in enforcing it than in enforcing discipline in the purely military sense. I have heard it said fairly frequently that the soldier could not be made to take care as to what water he drank ; that he would drink when he chose, and where he chose—in short, that water discipline could not be enforced. On that point I do not pretend to be able to judge. Of this, however, at least I am very certain. A unit whose officers cannot enforce water discipline cannot be a reliable unit in discipline generally, and to admit that the soldier will not, or cannot, be made to obey orders in this respect is to admit that he cannot be trusted to obey orders, except under such conditions as are agreeable to him personally.

Collection and Distribution in the Field.—I do not intend to go into much detail as to these points. In civilized warfare each unit will be accompanied by its regulation allowance of water-carts under charge of a specially qualified water party. The source of water is selected by the staff, in conjunction with the sanitary or other medical officer present, and safeguarded, as far as possible, from pollution. That is to say, the best water that can be found is selected, though it is, of course, often necessary to choose an obviously polluted source and make the best of it. On this point I will make only two remarks. Firstly, all water on service, except that which comes from a regular municipal piped supply, must be looked upon as polluted, in the sense that it must not be drunk without preliminary purification. Secondly, in spite of the fact that the water is *ex hypothesi*, or even obviously, polluted, that affords no reason for increasing the already existing contamination. On these statements certain corollaries hang. If the water is polluted, then, obviously, no individual should be allowed to have access to it until it has been purified. In the "Field Service Pocket-Book" it is laid down that "men must be prevented from drinking water from unauthorized sources." This lacks only one thing—namely, it does not define an

"authorized source." As a matter of fact, no man should be allowed access to the *source* at all. He should go to some place where the purification apparatus for his unit is installed, and fill his bottle there. The water parties of the various units are the only people who should be allowed to approach within a certain definite distance of the source itself, and this they should do at regular times and in a regular manner. In the next place, as few even of these men should go to the actual edge of the water as are absolutely needed for the proper drawing of the water. If the regulation water-cart is in use, one man only need carry the end of the hose-pipe and place it in the water; if buckets have to be resorted to, then a line of men must be made to pass the filled buckets up and the empty buckets down. There must be no unnecessary coming and going near the water's edge. No animals should be allowed to come close to the water, and, if necessary, the draught-horses of the water-cart must be unharnessed and taken to some little distance whilst filling is going on. In any case a small catch-water drain must be made, to prevent the trickling of urine or dirty water back to the source of supply. Of course, cases will occur where, owing to the local conditions or the weather, it is practically impossible to do anything, and where additional pollution is inevitable. Cases may even occur where, owing to the hardships of the march, the men must be allowed to drink anything they can get hold of. One cannot legislate for such exceptions. There need be no more difficulty in arranging for a systematic method of distribution in the case of water than there is in the case of ammunition. Both may, under stress of circumstances, break down, but that affords no excuse for neglecting either under ordinary conditions. As I have already said, the whole question is one of discipline, and though the expressions "fire discipline," "march discipline," and "water discipline," are convenient ideographs to express certain sides of military activity, still, every soldier knows that there is, in reality, only one discipline, and that is obedience to orders from a superior officer. The officer or soldier who exercises a liberty of choice as to which order he will obey and which he will disregard, at the dictates of his own appetites, is no longer disciplined in the true sense of the word.

CHAPTER X

PURIFICATION OF WATER

The purification of water consists in the removal from or destruction in the water of those substances which have been added to the water in its passage through the air and through or over the earth, which are either dangerous to health or render the water unsuitable for use. In practice purification is limited to the removal of hardness and the removal or destruction of disease germs and other suspended matter. In exceptional cases, where the only water available is undrinkable on account of an excess of saline constituents, as in the case of sea-water, distillation may be resorted to, with a view to purification. Such cases are, however, exceptional in military practice.

Removal of Hardness.—Temporary hardness is removed either by boiling, on the small scale, or, on the large scale, by the addition of milk of lime to the water. This combines with the carbonic acid dissolved in the water, forming an insoluble carbonate of lime. The carbonates which the water was previously enabled to hold in solution, in virtue of the carbonic acid of which it has now been deprived, sink to the bottom, together with the newly formed carbonate. At the same time a considerable number of micro-organisms are removed from the water by precipitation. This process is usually termed "Clark's process." There are various modifications in which the water is strained through cloths, or passed through filtering towers, after addition of the milk of lime ; but the principle is the same in all. Permanent hardness may be removed by the addition of carbonate of soda.

In military sanitation, however, by far the most important aspect of water purification is that which is directed

to attacking the disease germs contained in water. These may either be removed from the water or destroyed in it. Removal is effected by sedimentation, precipitation, or filtration ; destruction by the agency of heat, light, or chemicals.

Sedimentation.—In this process the water is allowed to stand in or flow very slowly through uncovered settling tanks. It is extremely efficacious, especially as regards the specific organisms of disease, which do not, it is probable, live long under such conditions. As a preliminary to filtration, sedimentation is undoubtedly useful, but it is seldom relied on alone. Personally, I am not sure that in India sedimentation would not be preferable to sand filtration, with all the inevitable dangers attending on cleaning by native labour. The original expense of construction is the great objection, since a fortnight's sedimentation should be allowed. Upkeep charges are, however, reduced to a minimum.

Precipitation is not used (except in the Clark process, already described) on the large scale. On service, the addition of alum to muddy water has a wide range of utility in this direction. A large flocculent precipitate is formed, which sinks slowly to the bottom, entangling a large number of bacteria. As an adjunct to filtration this process is useful, and, in my opinion, gives us the most rapid and efficacious method of clearing grossly polluted water.

Filtration.—The term " filtration " is applicable to any method in which a mechanical obstruction is placed in the way of the flow of the water, in such a manner as to allow the water to pass through apertures in the obstructing material, whilst holding back a greater or less proportion of the particulate suspended matter. The obstruction may vary in degree from that imposed by a coarse rough cloth to that caused by a close-grained porcelain candle, and the efficacy of the resulting filtration will vary accordingly. Certain rules are, however, applicable to all filtration, whatever its degree, and it is advisable to clear the ground by stating these first.

The first rule is that the amount of resistance opposed to the flow of the water is inversely proportional to the size of the apertures in the obstructing material or filter. The

second is that the degree of purification effected is also inversely proportional to the size of the apertures, and therefore directly proportional to the amount of resistance.

Obviously, the greater the resistance, the greater the power necessary to force the water through the apertures of the filter. But since the degree of purification effected is directly proportional to the resistance, it must also be directly proportional to the power available. And, on the other hand, the power necessary is directly proportional to the degree of purification desired. These constitute the third rule. The fourth rule is that the rate of filtration varies directly with the filtering area available, directly, also, with the power available, and inversely as the resistance offered.

If a high degree of purification is required, we must interpose a great resistance. If that purification is required rapidly, we must either increase the filtering area or the power exerted, or both. As a matter of fact, for purely mechanical reasons, it is impossible to increase the power above a certain limit without damaging the material used for imposing the resistance, so that rapidity is largely a question of increased filtering area, if a high degree of purification is desired. On the other hand, it is possible to increase the rapidity, the filtering area remaining constant, by lowering the standard of purification, since in this way we lessen the amount of obstruction necessary. When both the area available and the power are limited, as is the case in the field, rapidity of output means a low standard of purification ; a high standard of purification means a delayed delivery.

The above statements seem so elementary as hardly to be worth repeating at such length, and so circumstantially. I do so because, obvious as these rules are, they are constantly forgotten. Inventors frequently claim that they can achieve purification of a high degree with resistance of a minimal amount, which can be overcome by a minimum expenditure of power, and in the shortest period of time. Sanitary officers must keep constantly before them the fact that filtration is not an esoteric process, but merely straining " writ large " in three syllables instead of two. The rules which regulate straining through a pocket handkerchief

regulate equally straining (commonly called "filtration") through a sand filter-bed, or a porcelain bougie.

Filtration on the large scale is carried out most commonly —in England, at least—in what are called "sand filter-beds." These consist of large tanks, about 5 feet in depth, which are filled from below upwards with coarse gravel, fine gravel, coarse sand, and fine sand. The thickness of the different layers varies in different installations. Beneath the lowest layer is placed a series of drains, intended to collect and lead away the filtered water. These beds are intended to remain constantly submerged in water, which slowly filters through them. The force is applied by the head of water in the tank, and is directly relative to this. The resistance is imposed at first by the fine sand, but this is not sufficiently great to bring about any high degree of purification. After the lapse of a short time, the duration of which depends on the impurity of the water, a gelatinous film is formed on and in the upper inch or two of the fine sand, due to bacterial and infusorial growth. This is termed a "zooglœa." The resistance opposed by this is considerable enough to bring about a very satisfactory amount of purification, and since this demands an increase in power, the water on the top of the sand increases in depth, thereby giving a greater head of water. As the zooglœa gradually becomes denser, so the purification increases; but the filtering area, being constant, the rate of flow diminishes, and as the obstruction demands increased power, the depth of water also increases. Eventually the head reaches a point at which either the tank can contain no more water or the pressure is sufficiently great to injure the filtering film. The bed must now be thrown out of action, the upper few inches of sand skimmed off, and then the cycle begins again as before. Eventually, when the fine sand has been gradually, in the process of successive cleanings, reduced to a layer of about 15 inches in depth, the bed is remade up to the original level. The usual rate of filtration through such a bed is not more than 2 gallons per square foot of surface per twenty-four hours.

Undoubtedly the greater part of the filtration occurs during the passage of the water through the zooglœa, which removes about 70 per cent. of the micro-organisms present.

The remainder are retained in the upper 15 inches or so of the fine sand, and it is on this account that, in cleaning the filter, it is advisable to leave at least this depth of that material undisturbed. The lower layers act merely as a support to the filtering layer, and it is important that the materials of which they are composed should be so graded and arranged that all sudden variations in the rate of flow of the water may be avoided. A constant rate of flow is absolutely necessary if satisfactory filtration is to be maintained.

Such a filter-bed will give a filtrate containing a greatly reduced number of micro-organisms, but absolute sterility is never attained. For this there are several reasons. In the first place, a certain number of the bacteria originally present in the water may find a passage through the filtering medium, but, in addition to these, there are always a certain number of water bacteria living in the depths of the filter which are gradually washed through into the filtrate. The importance of these is considerable when we are dealing with a comparatively pure water. If the number of micro-organisms in the raw water is small (according to Reinsch, below 200,000 per c.c.), it is impossible to estimate the filtering efficiency of the bed by a comparison of the number of germs in the raw water and the filtrate respectively, since those present in the latter bear no relation, either as regards number or origin, to those in the former. In such cases it is necessary to lay down a minimum standard of germs actually allowed to be present in the filtrate, which is arbitrarily fixed at 100 per c.c.

It must be remembered that pathogenic bacteria are somewhat peculiarly situated in regard to the possibility of their finding a passage through a filter. It is but rarely that they exist in the water as isolated individuals. More frequently they are contained in small particles of fæcal matter or mucus, which are easily held back by the zooglœa. From this point of view, Spitta considers urine containing typhoid bacilli as a much more dangerous source of water infection than a specifically contaminated stool. On the other hand, it is probable that isolated typhoid bacilli, even if present in large numbers in the water, would have but a poor chance of surviving in the struggle for

existence with the hardier water organisms living in their natural medium. When a man contracts enteric fever by drinking contaminated water, I should imagine that he does so, not by ingesting numbers of isolated bacilli, but by swallowing one or more small particles of fæcal matter or mucus in which these micro-organisms are sheltering. It is permissible, therefore, to accept as satisfactory a standard of filtration which falls considerably short of absolute sterility, even though that implies a certain number of bacteria which exist in the raw water are actually passing through the filter.

Owing to the extremely slow rate at which the water passes downwards through the filter-bed, it is at least possible that some biological action comparable to that which is met with in a sewage filter occurs during the process. Unless the raw water is grossly contaminated with organic matter, however, this is not likely to be sufficient to effect any marked change in its chemical constitution ; and it is safe to say, with Proskauer, "that the chemical character of a filtrate is the same as that of the unfiltrated water." It is impossible, therefore, to impose any chemical test of filtering efficiency.

It is clear that in a filter-bed such as I have described, where the raw water is submitted at once to a filtering resistance capable of keeping back the smallest particles, there is a certain want of economy of effort. A great deal of the suspended matter in water is of, comparatively speaking, a gross nature, and can be kept back by a straining medium of a much less delicate nature than the zooglœa of a sand filter-bed. It is possible, therefore, by submitting the water to a process of rough straining, to diminish the pressure thrown, as it were, on the fine bed. In the Puech-Chabal system an attempt is made to combine such a process with one of aeration. The raw water is passed through a number of filter-beds, containing material of gradually increasing fineness, and each, in consequence, somewhat larger in area than that preceding it in the series. These are arranged in a descending "stair," and the water is made to cascade from one "step" to the next. By this means a thorough aeration is effected. The last bed of the series is an ordinary sand-filter. It is not necessary to

clean this bed oftener than once in six months, and the interval may extend even to a year.

The cleaning of sand filter-beds is undoubtedly the great drawback to their use, and this drawback is considerably magnified when the cleaning process has to be carried out by low-class native labour, as in India and elsewhere. Any means by which this can be done away with or postponed possesses a distinct value from the point of view of military sanitation.

Mechanical Filters.—In order to simplify the process of cleaning, and also to increase the rapidity of filtration, various forms of mechanical filter have been introduced, principally in America. Of these, the best, in my opinion, is the Jewell system. In this form of apparatus the water, to which a certain amount of alum has been added, is led through sedimentation tanks, and then passed on to the surface of a sand-bed, which is supported on a frame at the top of a high metal or masonry cylinder. A dense film rapidly forms on the surface of the sand as a result of the addition of the alum, and this replaces in function the organic zooglœa of the common sand filter-bed. The formation of this film is so rapid that the flow of water is quickly impeded, and washing becomes necessary. To effect this, the direction of the current is reversed, whilst at the same time the mass of sand is effectively stirred up by revolving rakes. This process, which only occupies a few minutes, may need to be repeated several times in the twenty-four hours. The washing-water is allowed to run to waste. This system has been found to possess a high degree of efficiency, combined with great rapidity. The force employed is that of gravity, acting by virtue almost entirely of "negative head." For countries where a low-class native labour has to be relied on for cleaning filter-beds, I consider the Jewell system most satisfactory. The first cost of erection is high, and a certain amount of skilled supervision is required. These filters are peculiarly efficacious in dealing with water containing extremely fine silt. They should be very useful under conditions such as I have just noted, where difficulties arise in connection with cleaning.

The Bell filter is constructed on much the same lines, and

worked in much the same way as the Jewell. There is not, however, the same arrangement for preliminary sedimentation. The Bell is a good filter for use in cases where a certain amount of vegetable, and perhaps some animal, pollution has occurred, but where there is no probability of specific contamination by human excreta. It is eminently suitable for use with water from an upland grazing ground. The delivery 7 is gallons per square foot per hour. Washing is effected as in the Jewell filter, by reversed flow. In the Candy filter the water is passed through blocks or layers of magnetic oxide of iron, but before this is done air under pressure is injected into the water. This form of filter is extremely efficacious, especially in cases where the water is heavily tainted with chalybeate matter, or contains fœtid gases. An installation at Longmoor, near Aldershot, works well with a water of this nature.

Lemoine describes, under the appellation " non-submerged sand filter " (*filtre à sable non submergé de Miquel et Mouchet*), an installation which was adopted in the French Army in January, 1909. The theory on which this filter works is that " purification of water consists in a fixation by the means of the sand grains of all solid particles in the water, as a result of an attraction analogous to that of gravity, or by means of adhesion due to capillarity. This action takes place throughout the entire depth of the sand-mass." Such purification comes into action immediately the water comes into contact with the sand, and it is not necessary to wait for a process of " ripening " to develop, as in the case of the submerged sand filter. The rate of filtration is 2 cubic metres of water per square metre of sand surface (22·6 gallons per square foot). If too rapid a flow is attempted, the sand particles are disturbed, and purification does not occur. These filters are composed of layers of sand and gravel of various thickness, with a supporting substratum of bricks, and are built up inside receptacles, made of metal or masonry. The different layers run as follows from above downwards :

1. Fine sand, 1 millimetre (0·04″) gauge .. 1·5 metres (4′ 9″).
2. Coarse sand, 0·3 c.m. (0·12″) gauge .. .. 5 c.m. (2″).
3. Fine gravel, 0·5 to 1 c.m. (0·2 to 0·4″) gauge 5 c.m. (2″).
4. Coarse gravel, 2 to 4 c.m. (0·8 to 1·6″) gauge 5 c.m. (2″).

These layers of sand and gravel are supported on two layers of bricks. In the upper of these the individual bricks are laid flat in rows 1 to 2 centimetres (0·4 to 0·8 inch) apart, whilst in the lower the bricks stand on end and the rows are separated by an interval of from 4 to 5 centimetres (1·6 to 2 inches). The former act as a support for the superincumbent filtering mass ; the latter serve the purpose of under-drainage. Lemoine shows in his illustrative diagram a thin layer of coarse sand on the uppermost surface of the fine sand, intended presumably to act as a protection to this latter. The thickness appears to be about 1 inch.

The water, which is first passed through a roughing filter, flows on to the surface of the fine sand through a coiled tube in which small holes are bored ; these average ten or twelve to the square metre of surface. Care must be taken that no jet of water shall impinge on the sand surface within 20 centimetres (8 inches) of the wall of the chamber, and it is advisable to bank up the uppermost protective layer of coarse sand all round the edges of the filter in order to prevent any water that may pond up on the surface from finding a passage between the sand-mass and the retaining walls. The delivery tube for filtered water should be as close to the bottom of the filter as possible, and of such size that there shall be no obstruction of the flow. A tube of 1 centimetre (0·4 inch) will allow of a discharge of 4,000 litres (880 gallons) in the twenty-four hours. The surface of the filter should never be less than about half a square metre (say 5 square feet). The size should be such as to give a *per capita* allowance of 10 litres (2·2 gallons) per day, at a filtration rate of 2,000 litres (440 gallons) per square metre (9·9 square feet) of surface.

The filter should not be placed so as to be exposed to the action of the direct rays of the sun, which encourage the growth of algæ, thus leading to rapid blocking of the apparatus. It should stand in a dark place, or, at most, in a diffused light only. It must be protected from frost. According to Lemoine, in the first days of working, the effluent possesses more micro-organisms than the raw water, due to the washing of bacteria out of the filter mass. After a few weeks the micro-organisms found in the filtered water are only those which grow in the lower layers of the sand

and gravel, their number depending greatly on the amount of nutritive material in the water. Pathogenic bacteria are said to be entirely eliminated, and, according to Miquel, the *B. coli* does not penetrate farther than the upper half-metre (20 inches) of the fine sand. Good results appear to have been produced in some of the French garrison towns where this system has been installed.

The non-submerged sand filter has one great advantage over the submerged filter, in that it is not necessary to resort to periodical cleaning, which is undoubtedly the great objection to the latter form. *A priori*, one would imagine that in filters of any size the difficulty would be the same as in the case of streaming sewage filters—namely, to get complete satisfactory distribution of the water throughout the sand-mass. Where comparative experiments have been made with the two types of filter working under the same conditions, as has been done at Marseilles, the older type seems to have been undoubtedly the more efficacious of the two.

Filtration on the small scale can be carried out by means of the so-called "domestic filters," which are usually made nowadays of porcelain or a composition of infusorial earth. These "candle filters" are of widespread use in different services in the field, and in some places in barracks.

Individual candles are most efficacious, but experience of battery-filters composed of several candles has not justified the expectations once entertained with regard to them. The great difficulty, especially in the tropics, where they are most likely to be needed, lies in the perishable nature of the rubber washers used. The opinion of Médecin-Inspecteur-General Vallin, quoted by Lemoine (p. 323), is so apropos that it seems worth reproducing in full. "These filters have now been in use in many barracks and hospitals for fifteen years, and have rendered inestimable services. In many cases they have put a stop to obstinate outbreaks of disease —true endemics, in fact. They have reduced by one-half the incidence of typhoid fever in the army. At the same time we have had a long experience of the minute care and the worry entailed by the weekly dismantling, cleaning, inspection, and refitting of 150 fragile candles, and of an equal number of receptacles placed below them. Whenever this supervision is momentarily relaxed, whether as a result

of the slackness attendant on prolonged effort or other causes, the filters rapidly get out of order ; they may even become sources of danger from the false sense of security they furnish." This sums the situation very well, I think. Filter candles are like many other appliances—excellent when used as units, but unreliable when used in mass.

In the field, filters are used by us in the form of the filter water-cart, of which a detailed description is contained in "Royal Army Medical Corps Training." In principle this consists of a rough strainer, formed of compressed sponge, from which the water passes to porcelain candles, each discharging separately in such a manner that the output of each individual candle can be checked. Experiments are in progress to substitute a strainer, consisting of cloth stretched on a cylindrical wire framework, for the sponges. Using this, and adding 1 grain of alum to the gallon of water, it has been found possible to strain Thames water absolutely clear within a few minutes of starting the pumps. A thick deposit of slimy mud is formed on the outer surface of the cloth, which eventually furnishes so great a resistance to the flow of the water as to produce a high degree of purity. The force used is limited to 40 pounds to the square inch. I have come to the conclusion that bacterial purification is practically impossible, under field service conditions, with any resistance less than the above. Mule-pack and coolie filters have been designed on the same plan as the water-cart filters.

In the French Service both separate and combined candle filters are used. In the former (*filtre Berkefeld de campagne*) a single filter candle is enclosed in a metal tube, and the water forced through by means of a semi-rotary pump. The whole is mounted on a collapsible tripod. This pattern resembles closely a form once in use in our Service, but since discarded. The delivery at the start is at the rate of 45 litres (9·84 gallons) per hour, but diminishes after the first fifteen minutes. In the larger form (*filtre Chamberland de campagne*) twenty-one candles are used. The connection between the candles and the collecting chamber is effected by a special attachment which replaces the usual cemented base, and lessens the risk of fracture. The candles are enclosed in a cylindrical case 14½ inches in height, and 12½

inches in diameter. The weight of the total whole apparatus is 50 kilogrammes (110 pounds).

In the German Army a small portable filter is used, consisting of a candle enclosed in a metal case and a foot-pump, like that used for inflating bicycle tyres. This is carried at the back of the man's knapsack in the place usually occupied by the mess-tin. It weighs 3 kilogrammes (6·6 pounds), and delivers 3 litres (5¼ pints) per minute. This discharge would certainly fall off in a very short time. A compound filter is also used, consisting of nine candles in a cylindrical metal case ; to this is attached a lift and force pump, and the whole is mounted on a light wheeled platform. The output of this apparatus is, at the start, equivalent to 15 to 20 litres (26¼ to 35 pints) per minute. As a matter of fact, however, it cannot, even with a fairly clean water, be calculated to furnish more than about 75 to 125 litres (16½ to 26 gallons) per hour. Hetsch, in Bischoff's "Lehrbuch der Militärygiene" (p. 309), states that on service the unavoidable accidents to which such a piece of apparatus must be subjected would almost certainly cause some leak with consequent chance of danger. In the South-West African campaign this filter rapidly got blocked up.

In the American Army the Darnall filter is largely used. In this the water, after the addition of alum and sodium carbonate, is siphoned from one bucket to another, passing through a cloth stretched on a cylindrical wire cage. The power employed is very slight, and the resistance that can be overcome low. A high degree of purification in any reasonable period of time is *a priori* not to be anticipated, and at the Royal Army Medical College our results have not been good. If the descending or delivery arm of the siphon were lengthened, more power would be available. It is only fair to say that in the United States fair results have been achieved—namely, a delivery of 50 gallons an hour, with a bacterial purification equivalent to 98 per cent. If any considerable quantity of water is required, a considerable extent of filtering area—in other words, a large number of filters—would be needed.

In the Japanese Army the Ishiji filter was used during the late war in Manchuria. This consists of a simple canvas conical bag, with two lateral arms or spouts. The apex of

the cone is closed. The spouts are filled with sponge and charcoal, and the water issues through these. Two powders are added—viz. : (1) Containing potassium alum, potassium permanganate, and aluminium silicate ; and (2) aluminium silicate, tannic acid, and hydrochloric acid. The former is added to the water in the filter in sufficient quantity to cause discoloration ; the second powder is then gradually stirred in till the colour disappears. In this filter the power is supplied by the head of water in the cone, and depends on this being kept full. The method is simple, and a similar piece of apparatus could easily be improvised.

Various improvised methods of straining may be used on service with a view to removing gross contamination, the particular appliance varying with the materials available. These are familiar to most officers, and I will not dilate further on them.

General Remarks on Filtration in the Field.—A water may be free from disease bacteria, and yet demand filtration on account of gross pollution, sand, mud, floating débris, etc. On the other hand, a water may be perfectly clear, and, indeed, of the most inviting appearance, as, *e.g.*, in a chalk stream, and yet be dangerously polluted. The same methods of purification are, obviously, not applicable in both these cases. In the first some form of gross straining is required to make the water sightly, and this is necessary whatever subsequent method of purification be adopted. This can readily be achieved by a thick cloth strainer stretched on a framework. This framework may be either in the form of a cylindrical cage, such as already described, or in that of a long spiral of fine wire. In the latter form a greater filtering surface is available, giving, therefore, a larger output with the same force. The cylindrical strainer is, on the other hand, more easily manipulated. Alum should be used to cause a deposition of mud on the cloth, after which the degree of purification produced will gradually increase as the deposit increases in thickness, until at last the power available is no longer capable of forcing water through the clogged meshes of the cloth. In such a case, when the water is obviously polluted, the greater the amount of dirt present, the greater the degree of filtration ; and when the water is extremely foul, sufficient bacterial purifica-

tion can be effected by this method without recourse being had to any further process. On the other hand, a clear water—*e.g.*, that from a chalk stream—demands no such preliminary straining on the one hand, whilst on the other there is not present in the water the mud needed to produce a filtering slime on the cloth. The same fact has been noted by Nankivell (*Journal of Hygiene*, July, 1911) in the case of sand filters. In such a case, if filtration be adopted, some form of candle filter must be used to insure purity. It must be remembered that in the field, or elsewhere, it is not necessary to go as far as absolute sterility of the water for all purposes. For washing, cooking, or making tea, it is only necessary that the water should contain no great amount of visible dirt. To achieve this, straining of the simplest kind is all that is necessary. On the other hand, a clear chalk stream, even if polluted, is extremely unlikely to give rise to disease when used raw for ablution, cooking, or making tea. It can therefore safely be used for these purposes, untouched. It should be a strict order at all filtering installations in the field that no water is to be served out for washing, cooking, or making tea, which has been subjected to candle filtrations ; such water should be reserved to fill water-bottles ; it is too valuable to waste in other directions.

Filtration is at present, and will probably for some time continue to be, the best means at our disposal for the purification of water in the case of troops on the move. The great advantage possessed by filters is the fact that no extra stores, such as fuel, are necessary for their efficient working, and that they can be set to work at the shortest notice—as, for instance, during a midday halt. The great defect of all filters is unreliability. Whatever form is used, it is almost impossible to avoid having, at some point or other, a joint between the actual filtering material and a metal connection. The fact that these materials possess different coefficients of expansion under heat entails inevitably, sooner or later, the development of flaws in the process of sterilization. These flaws are often difficult of recognition, except as the result of minute and careful examination. Any marked solution of continuity will be revealed by an increased flow at the delivery pipe, but it may be permitted

to doubt whether the perspiring private who is operating the pump-handle against a resistance of 40 pounds to the square inch will be in a great hurry to realize—much less draw attention to—the occurrence of such an accident. In any case, a comparatively small pinhole in the cement of the joint which may let through a considerable number of pathogenic bacteria, will produce no obvious macroscopic effect on the output. Such a minute defect can only be identified by dismounting the candle and immersing it in water. Again, however reliable the filter candle, both as regards the material of which it is made and the permanence of its joints, sooner or later bacteria will grow through the pores of the material. This necessitates periodical dismantling, sterilizing, and cleaning.

All these difficulties can no doubt be circumvented or surmounted, but only at the price of a constant, almost meticulous, supervision. Unfortunately, though a state of war does no doubt encourage the development of many fine qualities, the faculty of continuous attention to minute detail is not on the list. In the case of filtration, more than any other system of purification, the medical officer in charge of a unit must pay particular and personal attention to the condition of the various parts of the apparatus, and the general working of the system. He will after a time realize the difficulty of avoiding a lapse into mere dead routine, and if this is the case with him, how much more must it be so in that of comparatively uneducated men, who are less qualified to realize the importance of the work. At the same time, though it is important to aim at as high a degree of purity as possible, it is at least open to question whether it is necessary to insist on absolute perfection—that is, complete sterility. This is an ideal state of affairs which is not achieved, or even demanded, in any municipal installation. Personally, though of course I should like to see 99·5 per cent. of the bacteria removed by my filter-carts under all circumstances, and would be inclined to insist on such a degree of success under laboratory conditions, when it is a question of actual field service I would be content to put up with a decidedly lower standard—say, 90 per cent of purification. Perfection is often apt to be the enemy of efficiency, and I think this is just one of those points where we must

be careful not to ask too much of Fate, in case she may decline to give us anything at all.

There is a point worth keeping in mind in connection with the filtration of water, more especially on field service, and that is the actual conditions under which the germs of disease are met with. When talking of filtration, the general idea seems to be that we have to deal with individual germs, and that our filtering material must therefore possess a texture sufficiently close to obstruct the passage of these extremely fine particles. Personally, I feel a considerable degree of scepticism on this point. In my opinion, the pathogenic organisms of intestinal disease are in the enormous majority of cases hidden in small masses of mucus or fæces, and that isolated bacilli which get access to water-supplies live a very short time indeed. When a bacteriological count of water sample is made, the masses of bacilli each form a colony, and one colony only—that is, one of them counts on the plate exactly the same as the isolated individual micro-organism. A purification of 90 per cent. means only that we have reduced the number of colonies to that extent, not the individual bacteria. If we could count the actual germs present before and after we should probably find the reduction caused by a good candle very much greater than that which the plate-counting method shows it to be. We are justified in my opinion, therefore, in allowing a considerable latitude, and I should feel inclined to look not so much to the actual number of colonies present as to the size of those noticed after filtration. The question is one demanding considerable further research, and at the present stage we are not, as I have already said, justified in being too meticulous in our requirements.

If germs are not removed from water by filtration they may be killed in the water, and this is done either by light, heat, or chemicals. Light is used in the form of the ultra-violet rays. These are produced in the lamps at present in use, from mercury vapour, rendered incandescent by means of an electric current. The principle is much the same in all cases. The mercury is contained in bulbs at the two ends of a vacuum tube made of quartz. The tube is rocked so as to cause the mercury to flow through it, whilst the current is running. The vapour left behind by

the mercury, as it rushes from one end of the tubes to the other, at once glows with a strong violet light. The sterilizing action of these rays is little short of marvellous, as long as the water is clear, but how it operates is not at present known. It may do so by producing ozone in the water, or by a directly lethal action on the protoplasm. The latter seems the more likely, since it is known that if the rays act for any length of time on the skin or conjunctivæ serious results may occur. In the Cooper-Hewitt lamp, manufactured by the Westinghouse Company, the lamp is contained in a cylindrical box, through which the water flows, being exposed to the action of the rays while passing over the edge of a conical diaphragm. The lamp is not in actual contact with the water. In the Nogier apparatus, on the other hand, the lamp is immersed in the water, and the same is the case in that manufactured by the Quarzlampen Gesellschaft of Hanau.

It does not appear that so far any use has been made of this method for field service, though in the *Deutsche Militarärztliche Zeitschrift* for June 5, 1910, and again for March 20, 1911, an account is given of two installations suitable for field use. One of these is intended to be self-supporting, manufacturing its own power by means of a small petrol motor and dynamo ; the former, at the same time, actuates the pump. The water is first strained through a roughing filter and then passed through Berkefeld candles. This latter seems a work of supererogation, and indeed the author has omitted this precaution in the later form. The water then passes through a Nogier lamp. The expenditure in power is 10 ampères at 139 volts, and the apparatus is calculated to supply 10 litres (17·5 pints) per minute. The whole is fitted up in a large four-wheeled waggon, total weight 2,420 pounds, at the back of which is a switch-board for controlling the electric attachments. In the second design the sterilizer consists of a roughing filter and Nogier lamp, carried on a small two-wheeled cart, fitted so as to be limber-drawn by either the Field-Röntgen Ray waggon, or the wireless telegraphy waggon. The current necessary in this case is 1·5 ampères at 110 volts, and the delivery the same as in the other pattern. A more detailed account of these two installations is to be

found in the *Journal of the R.A.M.C.* for May, 1911, under "Current Literature." * It does not appear that either of these installations has been actually built as yet.

Billon-Daguerre has suggested the use of a lamp in which the rays are produced in highly rarefied hydrogen, and claims for such a lamp more economical work, and greater efficiency at a less expenditure of power (only 2 ampères at 5 to 6 volts) than in any of the mercury vapour lamps. Undoubtedly we have in sterilization by ultra-violet rays the most promising method yet put forward. It is free from all the objections brought against heat and chemicals—namely, that of changing the character of the water in the first, or that of drugging the soldier in the second, case. It appears to be less open to defects than filtration, and is equally applicable whether with troops on the move, or in standing camp.

Sterilization by Means of Chemicals.—Chemicals can be used to destroy the micro-organisms in water in two ways. They may act either as oxidizing agents or as direct protoplasmic poisons. In the former class are included most prominently ozone and permanganate of potassium; in the latter the various halogens, chlorine, bromine, and iodine, and also sulphuric acid.

Ozone is used on the large scale in several forms of apparatus of which the Siemens Halske, and those of Frise, Otto, and Abraham and Marmier, are the best known. The ozone is produced as a rule by means of silent electrical discharges through previously dried air. The resulting ozonized air is then injected into the water, a thorough admixture being effected by various mechanical means. The different forms of installation vary only in this last respect. In the Frise sterilizer the water flows slowly upwards through a tower about 8 metres (26·4 feet) in height, its passage being obstructed by means of perforated celluloid plates, and the dissemination of the ozone throughout the mass being thus assisted. In the Otto sterilizer the water passes downwards through a tower into which the ozone is forced from below, thus meeting the flow of water. In the Abraham and Marmier method the same procedure is adopted, the tower, whose height is 7 to 8 metres (23·1 to 26·4 feet),

* See also *Journal* for February, 1912, p. 235

being loosely filled with gravel. The Siemens Halske method closely resembles this. According to Lemoine the Frise Company are meditating the production of a portable ozone sterilizer for use in the field.

Permanganate of potassium is the chemical most commonly used for oxidation of bacteria in water. In India at one time this salt was largely employed. In the absence of other oxidizable matter, in solution or suspension, the salt will inhibit the growth of disease-producing organisms. The action is slow, taking half an hour in the case of *Bacillus typhosus*, and a considerable dosage is necessary. If sufficient is used to make the result certain the taste and the colour of the water are markedly affected.

Lemoine describes several processes in which permanganate of potash or permanganate of calcium are used in combination with alum and other salts, the process being combined with rough filtration. The great objection to all oxidizing processes lies in the fact that the oxygen made use of exercises no selective action. Dealing with a water rich in organic matter, which is naturally often the case in polluted waters, especially in the field, the process of oxidation may extend itself on perfectly innocuous materials, allowing the bacteria, at which it is aimed, to escape.

The halogens are free from this reproach, and therefore, theoretically, more satisfactory. Chlorine can be evolved either from chloride of lime or from salt solutions by electrolysis. The former method was used with success at Lincoln, and works satisfactorily at Reading with the highly polluted water of the Kennet. In this last-named town the hypochlorite which is added to the water is subsequently removed by filtration through gravel and magnetic oxide of iron. The resulting effluent is absolutely free from all objectionable taste. In certain experiments made at the Royal Army Medical College, it was found that if water containing *B. coli* were pumped through a small receptacle containing bleaching powder (available chlorine 20 per cent.) and then allowed to stand for about five minutes *B. coli* was completely destroyed. The chlorine was still recognizable chemically at the end of this period, but not perceptible to the taste. The Ontario Provincial Board of Health recommend the use of chloride of lime in the following

manner : The salt is rubbed into a teacup of water, and the solution further diluted with three cupfuls. One teaspoon of the resultant mixture is added to each 2-gallon pail, and the water allowed to stand for ten minutes. Unfortunately this process depends largely on the chloride of lime being fresh and containing a large proportion (30 per cent.) of available chlorine. Used in the conditions for which it is advised by the Board of Health—*e.g.*, by prospectors, miners, and campers—this strength is not likely to be maintained. Moor and Hewlett recommend the use of bleaching powders in the proportion of 0·25 parts per million for clear chalk waters. The water should be allowed to stand for an hour.

Iodine is used by Vaillard, being liberated by the action of tartaric acid on the iodate of soda. After ten minutes the free iodine is absorbed by hyposulphite of soda. This process can only be used in comparatively small quantities of water. The salts are made up into tablets of different colours to facilitate their use in proper sequence. Testi of the Italian Army uses a solution containing free bromine and bromide of potassium, with hyposulphite of soda as a corrective. Schumburg, with a similar procedure, absorbs the excess of bromine with sulphate of iron.

Of the three haloids it can confidently be said that chlorine is by far the most useful. It is, to begin with, a normal constituent of the human body, and we know that it can be consumed in considerable quantity as chloride of sodium without ill-effects. It is different with the iodides and bromides, which are distinctly depressing in their action. Iodine and bromine should not, in my opinion, ever be resorted to, except in the absence of all other means of sterilization.

The acid sulphate of sodium is recommended by Parkes and Rideal. It is used in tabloids containing 15 grains for each pint, and imparts a distinct acid taste to the water. This is not unpleasant, and if it is made up as suggested by Firth, in combination with oil of lemon, the resultant liquid is palatable and refreshing. There is one consideration that, I confess, gives me pause. A man on service consumes at least half a gallon of water. Supposing half this to be taken in the form of tea, that leaves 2 pints

which must be sterilized by the bisulphate. It is a question for how long a period it would be wise to give the soldier 30 grains a day of a salt so closely allied to the well-known laxative sulphate of soda. Personally, I should strongly object to its issue for anything but the shortest period.

The great obstacle to the use of chemical methods of sterilization on service is the difficulty of distributing the agent evenly throughout the water. On the small scale, as in the soldier's water-bottle, of course this is simple enough. On any, even moderately, large scale it is out of the question unless some mechanical means is resorted to, and this at once robs the process of its greatest recommendation—namely, the fact that special apparatus is not needed. The objection of drugging condemns, in my mind, the use of bisulphate of soda, bromine, and iodine, and permanganate of potash, for any but the shortest periods. Another paramount objection to many of the chemical methods recommended is the complicated technique necessary. An extreme instance of this is shown in the following form of sterilization, recommended by Glaser (*Militärarzt*, February 25, 1910) : The apparatus necessary is packed in an aluminium case, 2 inches long by $1\frac{1}{4}$ inches in diameter. In this are contained the chemical reagents—viz., calcium permanganate and sulphate of manganese, each in concentrated solution, besides a number of filtering discs. The case is made so as to screw into the man's water-bottle at one end, the other being closed by a screw cap. The prescribed ritual of purification is as follows : One litre of water having been measured into the soldier's mess tin (the lid of which possesses just this capacity in the Austrian service) 5 drops of the calcium permanganate solution are added to this, and well mixed. The quantity of salt contained in this amount is 50 milligrammes. After the lapse of ten minutes 5 drops of the solution of sulphate of manganese are added. Ten minutes later a brown precipitate having formed, the aluminium case is screwed on to the mouth of the water-bottle over which a sterile filtering disc has been placed, and the now sterile water is filtered into that receptacle. The Austrian water-bottle only holds 500 c.c. of water, so presumably it is intended that the above process shall be carried out by the men in pairs. No

information is given as to the method by which the filtering discs shall be maintained in a sterile condition in the field. The same vice of complication condemns the processes of Vaillard, Testi, and Schumburg. Such methods may be classed amongst the many other " vain adornments " which encumber all departments of military activity after a few years of peaceful theory, only to disappear when the army " clears for action," or at the latest after a few weeks of warlike practice.

The officer who expects the ordinary careless man in the ranks to remember the order in which he is to place three different tabloids in his water-bottle, and the intervals he is to observe between the additions, displays a faith in the intelligence and power of self-restraint of the thirsty soldier more creditable to his heart than to his head. On the large scale, if the difficulty of mixing could be got over, this objection would naturally disappear. Ozone is free from all objection, but there is not at present any practicable method for applying it to field-service conditions. In short, I conclude that chloride of lime and bisulphate of soda are the only reliable chemical sterilizers that are at present at our disposal in war. They cannot be considered as being generally useful, but for small bodies of specially selected intelligent men, or small parties under the immediate control of an officer, and (especially in the case of the bisulphate) for short periods they may be of great assistance. Such conditions exist typically in the case of a small detached signalling party, or an officer's patrol of mounted troops.

Purification by Heat.—The simple boiling of water is undoubtedly the best way to insure its sterilization. In the case of the isolated individual or the small detached party, as long as fuel is obtainable and fires permitted, the problem presents no difficulty. The mess tin, or the camp kettle, can be used, and the subsequent cooling carried out in the water-bottle. With large bodies of men the affair assumes a certain complexity. In such a case some special form of apparatus is necessary to boil the water in, and some special means must be adopted to cool it subsequently. In some stations in India large standing boilers, called " Larrymore boilers," have been instituted. These

sterilized the water satisfactorily, but in no way assisted in cooling it. This had to be carried out in some open receptacle, and in the subsequent manipulation it not infrequently happened that all the benefit conferred by the boiling was lost. This was even more markedly the case where boiling was effected, as in the majority of cases, in large, open caldrons, from which the water was removed by means of pails dipped into them.

If it is desired to sterilize water by heat on the large scale, then it is imperative that some means must be provided whereby the process of cooling may be carried out rapidly, without exposing the water to any risk of further contamination. In the absence of any refrigerating apparatus this is effected most readily by means of "heat exchange." The principle of this method is that if two masses of water of different temperature are brought into close relationship, being separated only by a thin sheet of some good conducting material, they will tend to approximate in temperature, a rough balance being struck between the two. In all apparatus working on this system the incoming cold water is made to pass on one side of a thin metal sheet, whilst the outgoing hot water passes along the other. As a result the latter emerges from the apparatus not only sterilized, but cooled to a very considerable degree. Coincidently there is considerable economy of fuel, the cold water arriving at the boiler at an already somewhat raised temperature. In the German and French Armies large portable sterilizers of this nature are in use. In the former this consists of a four-wheeled waggon, carrying a boiler and cooler. The water is heated to 110° C., and eventually cooled to within 2° to 3° of its original temperature. The output is 1,000 litres, say, 220 gallons, per hour, and the weight of the entire apparatus 2,450 kilos, about 2 tons 8 hundredweights. Such a weight is prohibitive for a moving piece of apparatus, and it could therefore only be used in standing camps or in large forts. A smaller form suitable for pack transport, weighing 90 kilos (190 pounds), is also supplied. In the South-West African campaign both these sterilizers were found unsatisfactory, and unsuited for the climate. The chief objection to them seems to have lain in their great weight. In the French Service

three different types are in use—the Vaillard and Desmaroux, the Malvezin, and the Maiche-Cartault. These only differ from each other in the means by which the two moving masses of water are brought into relation to each other. In the Vaillard-Desmaroux method (*Sterilizateur Salvator*) this consists of two metallic sheets, rolled concentrically on each other in such manner as to leave between them two channels, of exactly equal capacity. The output is 1,000 litres per hour, and the apparatus is not portable.

In the method of Malvezin (*Sterilizateur Pastor*) the two masses of water are separated from each other by thin metallic corrugated plates, made of a specially prepared bronze, covered with a fine enamel. The currents are broken up into thin horizontal films, "which may be compared to two ribbons interlaced in a zigzag fashion, the one moving from above downwards, and the other in the opposite direction" (Lemoine). In the *Sterilizateur Maiche-Cartault* the exchange takes place in helically coiled tubes. In all these forms of apparatus the temperature of the water is raised very considerably above that which is necessary to destroy the germs of the ordinary water-borne diseases. This entails an unnecessary expenditure of fuel.

It has been proved by direct experiment that a momentary exposure to a temperature of 80° C. is sufficient to kill the micro-organisms that cause cholera, enteric fever, and dysentery. In the Griffith sterilizer, used in our army, this fact is made use of. This consists of a boiler and an exchange cooler as in the case of the other patterns, but the passage of the heated water from the former to the latter is controlled by a valve, operated by a small capsule, which contains a mixture of alcohol and ether boiling at 80° C. This guarantees that no unsterilized water can pass through the cooler. The saving on fuel is considerable, and the taste of the water is not affected to the same extent as with the ordinary models. This pattern has not undergone the test of field service, but has worked well in camps in this country. The largest stationary pattern is calculated to deliver 100 gallons per hour. A portable form has been made, but so far has not proceeded beyond the experimental stage.

Sterilization by Heat in the Field.—It is very doubtful, in my opinion, if sterilization by heat can ever be of

practical utility in the field with troops on the move. The apparatus is necessarily bulky, and the method entails the provision of fuel, that is, additional transport. In civilized countries this, of course, would present comparatively less difficulty, though even here the collection and distribution of the necessary coal, wood, or oil, would entail extra duties on the part of the supply authorities. Again, whilst a filter cart can be brought into activity immediately on arrival in camp, any heat exchange apparatus demands a certain lapse of time before it can supply potable water. In uncivilized warfare the difficulties are even greater, since the fuel may have to be transported from the base, and the system would therefore add another weight to the many which hamper the activity of an independent column operating under such conditions. On the other hand, in stationary posts on the lines of communications, or other positions occupied for some length of time, this method presents certain manifest advantages. In the first place it demands much less supervision than any system of filtration, and can be maintained at work for much longer periods, and in the second it is much more certain in its action, when this is continued over a long time. A filter needs constant supervision, and periodical renewal, while flaws of even serious extent may pass undetected. The essential drawback to the employment of heat is the unpleasant mawkish taste that invariably results.

The Position occupied by Purification in the Water-Supply System.—Since water is at the moment of condensation in the atmosphere free from all possible contamination, the purification of water is a confession of inadequacy or weakness somewhere. This inadequacy may be the result of circumstances beyond our control, as, for instance, in the case of a large town which has to rely for its water on an obviously polluted river. In a great many cases, however—and this applies particularly to stations such as our troops occupy in India and South Africa—the demand is so comparatively small that it is, or should be, possible to select a source free from all possible contamination, which should yet be capable of supplying sufficient water for the garrison concerned. It must be remembered that we have to protect ourselves, not against an infinite number of

possible forms of pollution, but against practically one only—namely, pollution by human excreta. Moreover, we know that the bacteria which constitute the real and only danger are readily removed from the water by passage through a comparatively small thickness of soil or rock. If we can insure—and this is fairly often the case—that our water shall be collected off a perfectly pure surface—as, for instance, a fenced-off moorland—or, if from wells, that these are at least half a mile, measuring horizontally, from any polluted soil, and of sufficient depth—using the word in the sense defined in an earlier chapter—it becomes a question how far it is necessary to resort to purification at all. Yet I have not infrequently seen measures of purification, of an extremely crude type, resorted to under conditions where the necessity for any measures of the sort was extremely uncertain. It must be remembered that all purification means a certain amount of handling, and any scheme that is not carefully thought out may result in the actual addition to the water of the very germs which it was intended to remove. It is our duty, therefore, in the first place, to see that the source is free from danger (assuming, of necessity, that the amount available from this source is sufficient). The question of purification only arises when the source is obviously dangerous or liable to contamination, and the liability is of a permanent and irremediable nature. The adoption of purification, therefore, assumes either that one or both these conditions has been proved to exist ; is a proof, therefore, of imperfection, whether unavoidable or not, in our methods of collection. The adoption of duplicate systems of purification is even more illogical. I have seen cases where, after passage through sand filter-beds, the water was, nevertheless, boiled before issue to the troops. Clearly the sand-beds were either efficacious or useless. In the former case boiling was a work of supererogation, in the latter the filters should have been dispensed with. It may be wise to have two strings to one's bow, but it is bad archery to fit them both on to the bow at the same time. Briefly, the adoption of any method of purification assumes that up to that point in our system the water has been exposed to probable and unavoidable contamination.

If purification is necessary, it should be carried out under some central authority, and not, if it can be avoided, by the individual consumer, nor even by isolated groups of consumers. A centralized system of purification is much more likely to be efficacious, and much less likely to be dangerous, than one which leaves the details of the work to a number of scattered individuals. The inevitable loss of economy resultant on all decentralization of effort leads to inefficiency. I am perfectly certain that the boiling of water "under regimental arrangements," sometimes even "under company arrangements," as it used to be carried out in India in the late nineties, meant the risk, if not the actual certainty, of increased danger. Where purification is necessary, then, it should be carried out by some central station authority, not by individual units. If, however—and such occasionally may be the case—water cannot be purified in any central installation, then the opportunity should be taken to instruct the men in purification "under field-service conditions," and the methods adopted in peace approximated as closely as possible to those of war. On service, of course, all water is *ipso facto* contaminated, and must, therefore, be purified.

CHAPTER XI

VENTILATION

"VENTILATION" means the provision of fresh air to and the removal of foul air from the rooms of a dwelling, without the causation of draught. The most constant cause of the fouling of air is human respiration, and though other causes exist, such as emanations from the clothes and bodies of people using the room, or from the bodies of animals, and the products of combustion of illuminants, still, ventilation is considered chiefly in connection with the air needed for and expended in respiration.

The connection existing between the breathing of foul air and the causation of disease has always impressed itself very strongly on the minds of men. As is well known, the whole class of malarial diseases was at one time connected definitely by name with the inhalation of bad air, and in popular imagination a large number of other illnesses—such, for instance, as gaol fever—were attributed directly to the contamination of the air by some subtle gaseous emanation. This was probably largely due to the powerful impression produced on the imagination by the sense of smell, as is evidenced by the fact that in the Middle Ages the use of strong scents was considered one of the best prophylactics against infectious disease. The study of bacteriology has, of course, explained to a very great extent the part played by the atmosphere in the propagation of epidemics. The actual transference of micro-organisms as such—apart, that is, from fragments of fæcal matter, sputa, etc.—is very doubtful, and at the present day I should imagine that few people would credit the air itself with being a vehicle of disease, though its current may furnish the motive power required to transport the particulate matter which contains

the infective micro-organisms. Still, that the persistent breathing of "bad air"—to use the most convenient popular phrase—is connected with impairment of health is an undoubted fact, and, moreover, this "badness" is undoubtedly largely connected with the alterations produced in the air as the result of respiration. It is logical, therefore, to consider, first, the changes produced in air by this vital process.

Composition of Air.—Air consists normally of oxygen, nitrogen, and carbonic acid. The two former constitute the great bulk of the mixture, but, though the compound gas is present in infinitesimal proportions comparatively (3 to 4 parts per 10,000), it must be looked on as being essentially a normal constituent of the atmosphere. Its presence is necessary to the continuance of vegetable life, and thereby to that of the animal kingdom. The nitrogen is present, as far as we know, mainly as a diluent of the oxygen, and, though certain plants possess the power of fixing this gas, the property is rare, and absent entirely in the animal kingdom. The active agent of the atmosphere is, of course, the oxygen, which forms slightly more than one-fifth of the entire mixture.

Respiration produces certain chemical and physical changes in the air inspired. As regards the former, the oxygen is reduced from 21 per cent. to 16 per cent., the carbonic acid being raised from 0·03 per cent. to 4 per cent. At the same time the temperature of the outgoing air is raised approximately to that of the body, and it is saturated with moisture. Lastly, certain offensive gases, the result of putrefactive processes in the upper air and alimentary passages, and certain micro-organisms having a similar provenance may be added during the process.

In addition to the effects produced on the air of a room as the result of respiratory processes, we must include those due to the evaporation of perspiration, which in persons of uncleanly habits may add a very definitely offensive element to the atmosphere.

The results of breathing air thus contaminated may, if the condition is acute, as in the several cases of historical overcrowding, of which the Black Hole of Calcutta is the classical instance, be extremely serious. In that particular

tragedy, for instance, in which the conditions were aggravated by intense atmospheric heat and moisture, 23 individuals only survived in the morning out of 146 who had been shut into the room the evening before, whilst the survivors suffered for some time from symptoms of septic poisoning. On the other hand, people exposed to chronic overcrowding suffer from general malnutrition and anæmia, with a high death-rate from respiratory diseases, especially from phthisis. In the majority of cases the situation is complicated by the co-existence of poverty, and often by intemperance and general immorality; but the connection of chronic overcrowding and pulmonary phthisis is well shown by the diminution in the death-rate from that disease that has accompanied the improvement in the housing of the British soldier since 1860. In the year 1857 a Royal Commission was instructed to inquire into and report on the condition of barracks and hospitals in the United Kingdom. It was found that about one-quarter of the army lived in rooms affording less than 350 cubic feet per man; only about 6 per cent. of the force enjoying a *per capita* allowance of over 550 cubic feet. The death-rate on account of phthisis was far higher in the army than in the civil population of the same age. As a result of their investigations, the members of that Commission recommended that in future the accommodation in barracks should be calculated on the basis of an allowance of 600 cubic feet per man. This recommendation was gradually carried out, and has now for many years been universally observed. Coincidentally with this improvement in the housing conditions of the soldier the death-rate from tuberculosis has fallen from 2·78 to 0·31 per 1,000, whilst the invaliding rate has been diminished by 50 per cent. The improvement in this respect in the army has far outstripped the improvement that has also occurred in the civil male population of the same age, and the cause of that improvement has undoubtedly been entirely, or almost entirely, the increased accommodation allowed in barracks.

Since the effects of bad ventilation must be due to some one or more of the alterations effected in air by the process of respiration, it is necessary to consider the effects on the human body of these changes individually.

Effects of Increase of Carbonic Acid.—The increase in the proportion of carbonic acid present is so marked a feature of respiration that attention was early directed to this factor as a possible cause of the ill-effects of bad ventilation. This tendency was strengthened by the fact that the presence and amount of this gas is so easily recognized, and its quantity can be so accurately estimated, that it affords a very ready standard whereby to estimate the actual amount of respiratory impurity present. De Chaumont was the first to fix a standard in this respect, considering that any amount in excess of 6 parts per 10,000 of carbonic acid was associated with a sensation of " stuffiness " readily apparent to the senses. Other later observers have increased this somewhat narrow range of permissible impurity, and the Committee on the Ventilation of Cotton Weaving-Sheds prescribed a limit of 12 parts per 10,000, giving a margin of permissible impurity of over 8 parts, or four times that allowed by De Chaumont. This would probably be considered excessive in the case of a room occupied continuously as a dwelling-room, but at the same time we have ample proof that, as long as the carbonic acid present is not due to respiration, amounts much higher than these can be endured, not only without distress, but without the fact being recognized. According to Pembrey, it is quite possible to work in a room where the proportion of carbonic acid is as high as 60 volumes per 10,000, while at the same time this amount is not perceptible to anyone entering the room. This fact is now generally accepted, and though the percentage of carbonic acid is still retained as the simplest and most accurate test of the condition of ventilation in an inhabited room, it is recognized that the quantities present, even in the worst ventilated rooms, are insufficient to account for the effects produced by bad ventilation.

Effects of Decrease of Oxygen.—Since the amount of carbonic acid in expired air is roughly 100 times that in pure air, whilst, on the other hand, the oxygen is decreased only by 20 per cent., it might be anticipated that the effect of bad ventilation on the air of a room would be less obvious in the latter than in the former direction. As a matter of fact, the proportion of oxygen present even in the air of the

worst ventilated rooms varies but slightly in amount from that in the air of the open country. Angus Smith found in the air of a law-court which was not ventilated in any way 20·65 per cent. of oxygen near the door, and 20·49 per cent. under the lantern just as the court was closing—a diminution of only at the outside 2·5 per cent. of the average amount present in fresh air. A diminution so small as this can hardly be expected to have any effect, since an equal reduction in the actual amount of oxygen taken in at each inspiration would be effected by a very moderate increase in the altitude at which the sample was taken.

Effect of Putrescible Organic Matters added to the Air.—The very obvious effect produced by the air of a stuffy room on the olfactory organs, and the fact that this is in some delicate people accompanied by, and, as a result partly, no doubt, of unconscious suggestion, connected causally with, a feeling of nausea and faintness, has led many people to connect the bad effects of ventilation with the presence of these putrescible organic matters in the expired air. Experiments by Arsonval and Brown-Séquard led these observers to conclude that a poisonous alkaloid was actually present in such air; but later observers have decisively negatived this conclusion. It may be taken as proved that up to the present no definitely toxic substance has been isolated from air which has been vitiated by human respiration. So great an authority as Rubner, it is true, still adheres to the opinion that harmful matters do, nevertheless, exist in expired air, "though their nature, amount, and characteristics are as yet unknown." It is very doubtful if even this modified theory can be maintained. The sense of smell exercises so marked a bias on the mental processes that deductions drawn from it alone are most misleading, and demand support from more exact experimental observation. It must be remembered, too, that this sense is the most easily blunted of all, and a very brief exposure to the air of a "stuffy" room would deprive even the most sensitive of the power of recognizing this condition, by the sense of smell alone, in another equally objectionable apartment.

Effects of the Physical Changes in the Air.—There is no doubt that all recent work goes to show that the effect

produced by the air of a badly ventilated room is primarily due to the increase in temperature and humidity, and that these conditions are largely aggravated by any want of movement in the air. These changes exert their influence through the heat-regulating mechanism of the body. Under ordinary circumstances the body parts with the heat which it produces by radiation, convection, and evaporation. Radiation and convection can exercise but little influence in an inhabited room, much less in a crowded one, if the air temperature is anything over 65° F. Any motion in the air will, of course, bring ever fresh masses of air in contact with the body, and thus assist in removal by convection. In the absence of such movement heat loss must be effected almost entirely by evaporation, and the extent to which this is possible is entirely dependent on the relative humidity of the air. If this is high, evaporation ceases, or is diminished, and interference with the heat-regulating mechanism at once results. In any particular climate the relative humidity can be fairly well estimated by the reading of the wet-bulb thermometer, but this is an accurate guide under constant conditions only. Thus, a wet-bulb temperature of 74° or 75° is most oppressive in England, since the dry bulb is rarely much higher, and the figures given, therefore, connote a condition closely approaching humidity. In India, on the other hand, a wet-bulb temperature of 85° F. is compatible with a feeling of absolute well-being, so long as the dry bulb stands as high at least as 100° F., since the amount of relative humidity is then only 47 per cent. A high degree of humidity is oppressive, even at comparatively low temperatures, if the air be still; and, as is well known, a cold, stuffy room is only less objectionable than a hot, stuffy one. Movement of the air not only brings fresh cool masses of air into contact with the skin, but also assists evaporation. In a badly ventilated room the air in the immediate vicinity of the individual may be saturated with moisture, though that at a distance is still comparatively dry. In such a case mere agitation of the air will effect relief up to a certain point, even though the air of the apartment as a whole is not changed. There is considerable reluctance in some quarters in accepting the theory that the bad effects of ventilation are entirely due

to the physical changes produced in the air as a result of respiration, but at present certainly the onus of proof is on the shoulders of those who still adhere, like Rubner, to the suggestion that unknown toxic elements exist in expired air.

The Effects of Combustion.—The burning of illuminating gases or oils results in the production of carbonic acid and water, as well as in raising the temperature of the room. It has always been recognized that a higher proportion of carbonic acid could be allowed to be present in the air of an apartment, when its existence was due—in part, at least—to artificial illumination. Thus, in the Report of the Committee on Humidity and Ventilation in Cotton Weaving-Sheds, the carbonic-acid standard is laid down at 12 parts per 10,000, or 8 parts in excess of the amount present in the outside air, whichever be the greater, at ordinary times, but at 20 parts per 10,000, or 16 volumes in excess of the outside air, whichever be the greater, during the hours when artificial illumination by gas or oil is in use. This position at first seems somewhat illogical. Originally, no doubt, it was assumed, on the grounds that artificial lamps and gas-jets added no putrescible or offensive matters to the air, and that, therefore, the actual amount of carbonic acid thus produced was less significant than that which proceeded from human lungs. This position could not now be logically held. As a matter of fact, however, the proportion borne by the water produced in combustion, say, of coal-gas to the carbonic acid, which is the result of the same process, is very much smaller than the proportion borne by the water exhaled in respiration to the carbonic acid in the expired air. We are still, therefore, justified in being more lenient in laying down a carbonic-acid standard when artificial lighting is used than when this is in abeyance.

Estimation of the Amount of Air required.—Theoretically, this should be based on the amount necessary to absorb the moisture produced by respiration and perspiration, and would vary, therefore, with every variation in the temperature and relative humidity of the atmosphere. Actually, however, it is much simpler to use the carbonic acid present as a test and fix an empirical standard for

this. Having done this, it is a simple matter to estimate the amount of air necessary per head of the occupants of a room to be delivered per hour, if that standard is to be maintained. The amount of carbonic acid exhaled per hour varies with the size, age, sex, and occupation of the individual. For the ordinary sedentary adult an average figure of 0·6 cubic feet per hour is taken. If, now, we take a closed room measuring precisely 1,000 cubic feet in size, we know that this will contain about 0·4 cubic feet of carbonic acid. Taking De Chaumont's standard of permissible limit of impurity—namely, 0·6 parts of carbonic acid per 1,000—it is fairly clear that the average adult will have raised the percentage of carbonic acid in the room to this amount in the time taken by him to exhale $0·6-0·4=0·2$ cubic feet of carbonic acid. But since he exhales 0·6 cubic feet per hour, he will clearly attain this limit in twenty minutes. Therefore a fresh supply of 1,000 feet must be given at the end of twenty minutes if the standard is to be maintained. This amount will again be expended in twenty minutes, and a third in a similar period. Clearly, every individual will, taking the above arbitrary standard of impurity, expend 3,000 cubic feet of air per hour. Further, too, it is immaterial what the size of the room may be. It does not matter whether the fresh air comes from another room or from another part of the same room. If a higher standard of impurity be taken, as, for instance, that laid down by the Weaving-Sheds Committee—namely, 12 parts per 10,000—then, clearly, the allowance of air may be much smaller—only about 800 cubic feet per hour.

It would be undoubtedly more logical to fix on some standard of relative humidity, and to lay down that the air of an inhabited room shall not show a greater difference between the wet and dry bulbs than that shown by the outer air, within a certain permissible margin of variation. So far, no standard of this nature has been fixed. As a matter of fact, in dwelling-rooms no such calculations are made. In rooms such as concert-halls they may be of use, though great allowances have to be made for loss by friction in air-passages, etc. In practice a certain number of apertures are constructed to act as inlets and outlets, with reference chiefly to the number of individuals that may be

expected to use the room. These are supplied, as a rule, by windows, chimney-flues, and other openings, which permit of the free movement of air, and the extent of these is not fixed, in the great majority of cases, by considerations of ventilation, but on æsthetic or other more general grounds.

Inlets and Outlets.—These are apertures in the wall of a room, either intentionally constructed with a view to the entrance and exit of air, or at least made use of for that purpose. To effect this various appliances are used—*e.g.*, Tobin's tubes, perforated bricks, and similar devices. Taking inlets into consideration first of all, it is important to consider their actual *raison d'être*. This is to admit pure air. It is not to admit pure air mixed with the accumulations of dirt and débris that may have collected in some recess or another. All apertures intended for use as inlets which are not easily accessible for thorough cleaning, or which contain corners not readily visible, and whose purpose is not obviously marked on them, so that the necessity of such cleaning shall be recognized, are, in my mind, anathema. I am not speaking of public halls, but of dwelling-rooms, and in these I include barrack-rooms. The only inlet which is always and easily accessible is the window, and I hold firmly to the belief that the only inlet which should be allowed in a dwelling-room is the window. This aperture may be utilized in various ways, as by the Hinckes-Bird system, in which the lower sash is kept permanently raised by a false sill, and an aperture equivalent to the entire breadth of the window and about 3 inches deep, is available for the entrance of fresh air. The direction of the entering current is by this device deflected upward, and the draught thereby caused is less likely to be felt. A better apparatus still is the so-called "hopper-window," in which a glass hopper is attached to the lower sill of a sash-window, projecting into the room. The upper level of this hopper should be about 5 feet above the floor, and it should be so constructed that it can, when the window is shut, be folded up out of the way. For schools, hospitals, and gymnasia these are excellent. In barrack-rooms they would be too liable to breakage. Outlets may also consist of artificial apertures in the wall of a room, and in this case there is, *prima facie*, the less necessity for con-

structing them in such a way as to facilitate easy cleansing. In fact, however, the necessity is just as great in the case of outlets as of inlets. The reason of this is that whatever may have been the original intention of the designer as to the proper course of the air-currents in a room, their actual course will be decided by the relative position of the hot and cold surfaces of the room. Wherever there is a cold surface there will be down draught, and should an opening originally designed as an outlet exist immediately above that cold surface, the direction of the air-current will tend to be inwards through that opening, and not outwards. On the other hand, supposing that there is in the room one main source of heat, all the air in the room will be drawn directly towards that source, entering the room at every available aperture, and will pass directly upwards from it as it can find vent. In any dwelling-room where there is a fire burning, such an overmastering up-current exists, and it is safe to say that in such a case every opening in the room except the chimney acts as an inlet to supply the demands of the chimney up-current, whatever the original intention with which that opening was constructed. If the fire be considerable, then the draught of air will affect the currents, not only in the original room, but in the passages and other rooms immediately adjoining.

In short, it may be said that the only outlet of a room in which there is a fire is the chimney.

During the winter months the outlets and inlets of rooms in which fires are not lit will all become inlets to supply the air demanded by the rooms which possess fires. Thus, in an ordinary villa, where in the day-time there are fires only in the kitchen and in one or two rooms on the ground-floor, there will be a current of air in the house from the upper stories to the basement. Later in the night, as the bedrooms become warmed and the kitchen and sitting-room fires die out, the current will tend to be reversed. The ventilation of an ordinary dwelling-house, cut up as it is into a large number of rooms and passages, each with surfaces presenting different conditions as regards temperature, is one of the most complicated problems in sanitation, and it may be safely said that the responsibility of the designer ends when he has provided a sufficient number of

suitable inlets—that is, windows—and safeguarded all unsuitable apertures likely to become inlets as far as possible. The actual course of the air-currents in the house, once it is inhabited, is beyond the wit of mortal man to conjecture. It will vary indefinitely with the manners and habits of the occupiers. What is true of dwelling-houses is, in my mind, equally true of barracks. Here we have to deal, it is true, with fewer rooms, and these of a larger size. I should trust in winter to a fire in an open fireplace, and in the summer to open windows ; and at all times in the year I should insist on all doors and windows, as far as the weather permits, being wide open on all occasions when the men are out of the room. It is in this last resource that I am certain that the proper ventilation of barracks consists. It is important to remember that the private soldier comes from a class the members of which are, to state the case mildly, averse to excess in the matter of fresh air. They do not like open windows, and they will not, if they can help it, have open windows, when they are themselves in the room. The greater the reason, therefore, why the windows should be open as wide as possible when they are out of the room. As a practical point, it is advisable that the windows should be opened and closed by some method of gearing under the control of a N.C.O., and applying simultaneously to all windows on one side of the room. The best form is a sash-window, of which the top can be let down when wanted, or a hopper window, with a hopper at the upper part. In cubicle barracks each cubicle must be separately ventilated in this manner, the different hoppers being controlled by the N.C.O. of the corridor, not by the individual men.

CHAPTER XII

REMOVAL OF WASTE MATTERS

One of the most important of all the problems that the sanitarian has to face is how best to remove and dispose of the waste matters that result from the ordinary daily life of mankind. In military sanitation I confidently place these questions as being the most serious of all that arise in connection with the prevention of disease, since it is my experience that the diseases which we have chiefly to fight against in military practice are caused and propagated more by defective methods of disposal and removal of these waste matters than by any other means. Before considering these in detail, therefore, I should like to lay down certain general principles which seem to me to underlie all systems, and which must be observed carefully if any system is to be satisfactory and efficacious.

In the first place, then, I will classify these waste matters under two heads—physiological and economic. The physiological waste matters are the excreta, liquid and solid ; the economic waste matters are the various fragments of food and other débris, and the slop and other waters which are the result of the different processes of daily life, eating, cleaning of utensils, and so on. Now, as regards these two classes it is to be noted that the amount of the former is fairly constant for all classes of men, whether civilized or savage, consuming similar diets, whilst the quantity of the latter will vary directly with the extent of civilization to which the community concerned has attained. In any at all civilized community the second class is far more bulky than the first, and the problem of its removal and disposal is difficult in direct proportion to the degree of civilization and the size of the community. Obviously, then, whilst

the physiological waste matters form a constant factor in the problem, the other class is more or less variable, and under control, both as regards quantity and quality.

The reasons why these matters have to be removed and disposed of are three in number : (1) Since they are to a great extent of an organic nature, they are putrescible, and in the process of decomposition they produce offensive gases, which, if not in themselves actually the cause of disease, do undoubtedly lower the vitality of those exposed to them, and also certainly cause what is legally termed a "nuisance." (2) They afford a favourable breeding-ground for flies ; and (3) in the case of the physiological waste matters they may contain the germs of certain intestinal diseases which, by some means or another, and very largely by the agency of flies, may get access to the air, water, or food-supplies of the community, and thereby give rise to fresh cases of the diseases concerned.

These evil consequences can be absolutely prevented only by complete disposal of the waste matters, though the risk of actual disease or serious nuisance can be largely mitigated by rapid and distant removal. We must decide first, then, what we mean by the word "disposal." In the case of organic matters this can only mean oxidation, and waste matters of organic origin can only be said to be disposed of completely when their chief component elements—nitrogen, carbon, and hydrogen—are converted into nitric acid, carbonic acid, and water. It is important to note, however, that this process of oxidation need not necessarily of itself affect the vitality of the disease organisms which are—at least, potentially—present in the waste matters. It will only do so with certainty if it is carried out in such a manner as to result in a rapid evolution of heat, as in the case of incineration. Slow oxidation, which is the method most usually adopted, does not of itself destroy disease-producing organisms, and cannot, therefore, be looked upon as, strictly speaking, a complete method of disposal. Now, it is obvious that with any method of oxidation less rapid than incineration, if the waste matters are great in amount, there will inevitably be, especially in a warm climate, a certain amount of putrefaction and fly-breeding, and since at the same time the disease-producing organisms will be un-

affected, there will be grave risk of these last getting access to the air, water, or food-supplies of the community. Therefore it follows that this process of slow oxidation must not be carried on in the vicinity of any dwelling, and from this we deduce the corollary that removal is more important than disposal in all cases where incineration *in situ* is impossible.

Taking, for instance, an isolated community living in a sparsely inhabited country, it is clear that if by some mechanical means we can contrive to remove at once all waste matters to a distance of several miles, the problem of disposal may, as regards that isolated community, be allowed to stand over for subsequent consideration, as long as the direction chosen is not towards the quarter of the prevailing wind, and the locality selected for disposal not close to the water-gathering ground. Such a situation is by no means impossible. Any man who has served in India must know many stations in which it would be quite feasible to select a direction and a locality fulfilling the above conditions, which at the same time would not interfere with the health or comfort of neighbouring native communities, and in which, therefore, if only the purely mechanical problem of complete and rapid removal were solved, that of disposal would present no features of urgency. I want to insist on this preponderating importance of removal as compared with disposal, because men who have been accustomed all their lives to an automatic system of removal are very apt to forget its paramount importance in countries where the efficiency with which it is performed depends on the memory and energy of a low-class native. I would impress most strongly on every young officer going to India that, as regards disease prevention, the removal of excreta is infinitely the most important question that he will have to face. The closer the danger the greater the danger, and with every yard that the excreta are removed from the vicinity of barracks the danger diminishes in inverse ratio to the square of distance.

As regards this question of removal, it is obvious that the two classes of waste matters stand on a very different footing. The class which I have termed "economic" can only produce a nuisance. If allowed to accumulate for some time, the unpleasant odours evolved may, it is true,

have a detrimental influence on the general health; but there is no possibility, as far as we know, of putrefying organic matter producing enteric fever or cholera in the absence of the specific disease germs, which exist only in the physiological waste matters or excreta. In any case, the danger is not so immediate and pressing in the case of the former as it is in that of the latter, and it is on the latter, therefore, that we must concentrate our chief attention. The methods to be adopted for the removal of the two classes also differ. Rubbish is usually bulky, and is always insoluble. It cannot, therefore, be removed in any case except by actual porterage, by hand or cart. On the other hand, the excreta are in great part liquid, whilst the solid matter is small in amount, and readily disintegrated. They therefore readily lend themselves to removal by water carriage, which also solves the question of removal of slops and other waste matters.

The effect on disease incidence of the introduction of such a system of water carriage, which removes at once and to a safe distance all the specifically dangerous matters, besides a considerable amount of putrescible fluid, has been proved by experience to be so great that in all civilized communities a water-carriage system of removal is installed whenever possible. The reduction in the prevalence of enteric fever, as the direct result of the institution of a sewerage system, is one of the commonplaces of textbooks on sanitation, and need not, therefore, be repeated in detail. In fact, the efficiency of such a system is so great that any community which still retains a more primitive method of removal may fitly be called on to show cause for so doing. Such cause can only be furnished by proof that the difficulties in the way of installing and maintaining a water-carriage system are so great that it would be impossible either in the first place to carry out properly the mechanical laying of the necessary conduits, or, in the second, to insure their fulfilling their necessary function of rapid and complete removal at a subsequent period.

In certain places such cause can be shown, and here, therefore, it is necessary to fall back on a hand and cart system for removal of all waste matters. The different significance of the physiological and economic waste matters,

as I have termed them, now comes at once into play. Since, as I have already stated, it is the former only that are immediately dangerous, whilst the latter are merely the possible cause of nuisance, it is clear that the removal of the former is the urgent problem, and the task before us will be simplified by keeping the two different classes of waste matters separated. In a hand-and-cart system the great difficulty is presented by bulk of fluid. This, which is a positive advantage in a drainage system, as facilitating flushing, becomes a positive disadvantage when all dangerous or putrescible matters have to be carried away by man, or dragged away by animals. The excreta, liquid and solid, must therefore be kept rigidly apart from all slops ; they must be removed as rapidly and as frequently as possible, and, pending removal, they must be so enclosed that no particle of possibly infectious matter shall be able to find access to the food, water, or air supplies of the community. It is sufficiently clear as a mere matter of principle that if we can dispose immediately *in situ* of all such possibly infectious matters—as, for instance, by incineration in the actual latrine itself of all the excreta, the problem of removal of the other waste matters loses a great deal of its urgency, and in practice a good deal of its difficulty—a point to which reference will be made later. To sum up on the whole question :

1. Waste matters consist of two classes, of which one is positively dangerous until disposed of, the other in itself merely the cause of annoyance, though in the presence of the former it may assist in the dissemination of danger.

2. The disposal of both classes is achieved by oxidation, whether slow or rapid ; but whereas rapid oxidation will not only remove the danger, but also prevent the nuisance, slow oxidation will not affect the former, nor entirely prevent the latter.

3. Therefore, where rapid oxidation—or, in other words, incineration *in situ* — is impracticable, it is necessary to achieve early and complete removal, since at any moment both the danger and the nuisance are in direct proportion to the proximity of the waste matters to the habitations of the community.

4. This early removal is effected in civilized communities

by a system of water carriage, and its efficacy as a method of preventing disease has been repeatedly proved.

5. Where this method of removal by water carriage is impossible, it is clear that on general principles we should aim at immediate disposal *in situ* of the positively dangerous waste matters by rapid oxidation, which not only disposes of them *qua* possible causes of nuisance, but also destroys entirely their power of causing disease. It should be noted here that there is no proof that the methods of slow oxidation which are usually adopted for the disposal of waste matters in any way affect the disease-producing organisms that may be, and should always be assumed to be, present in the excreta. They must therefore be looked on from the point of view of disease prevention as theoretically incomplete.

Water-Carriage Methods of Removal.—The usual systems of water carriage begin with the water closet, are continued through the soil-pipe, the house drain, the branch drain, and the sewer, to their final termination at the sewage works. It is to be noted that we have here a closed system of pipes containing a greater or less quantity of putrescible fluid in more or less rapid motion. The efficacy of such a system depends, in the first place, on the rapidity with which the fluid is carried along the system of piping, since any delay permits of the accumulation of noxious gases which may pass backwards into the habitation. It is essential, therefore, that the onward flow of the sewage should be facilitated in every way, that there should be no constructional impediment, and that means should be provided whereby every accidental obstruction may be at once cleared away. At the same time, since a certain amount of putrescence, with consequent evolution of gas, is inevitable, there should be complete disconnection between the air of the house and that of the drainage system, and also free communication between the air of the latter and the general atmosphere.

The various methods by which the above objects are achieved are fully described in general textbooks on sanitation, and since the details of a drainage system in a modern barracks differ in no way from those in any civil institution, nor, indeed, except in extent, from those in a private dwelling, I do not intend here to touch further upon them, since they possess no distinctively military features.

Hand and Cart Methods.—I will accordingly pass at once to the system of removal by hand and cart which we are forced to adopt in stations where for various reasons a water-carriage system is impossible.

As I have already said, the advantages possessed by a water-carriage system are so great that the adoption of any inferior method needs defence and the submission of reasons. Obviously these must be grounded on local conditions which either tend to impede the onward flow of the sewage, or favour the evolution of gas in the drains, or produce both these effects. The flow is impeded by deficient fall, or by great length of comparatively narrow branch drains. Neither of these by itself is insuperable, since the former can be overcome by mechanical means, pumping, suction, etc., and the latter, if the gradient be satisfactory and the quantity of the sewage sufficient, is of comparatively less importance. Combined together, however, they constitute a difficult situation. Long branch drains mean a scattered community living in houses situated at a considerable distance from each other, and this, again, means, as a rule, a community with a small taxable capacity compared with the area that it covers. Propulsion or ejection systems are expensive in construction and upkeep, and, though they can overcome any difficulty the result of insufficient gradient, their efficacy is much diminished if the narrower branches form any considerable proportion of the whole drainage system. The evolution of gas is favoured by a high temperature, which, in addition, increases the volume of the gas so formed ; whilst, if an extraction system is to be adopted, free intercommunication cannot be permitted between the open air and that of the drain or sewer. Clearly, therefore, in a warm climate, with a community living in comparatively small detached houses, especially if the general surface be flat, the introduction of a water-carriage system of removal bristles with difficulties. I do not mean to say that they are necessarily insuperable difficulties. They can doubtless be overcome by a free expenditure of money and constant supervision, and with a rich community would probably be overcome. Now, the condition of affairs in the enormous majority of our Indian stations is as I have stated three sentences above. For these reasons, I have come to the conclusion that to intro-

duce a water-carriage system in these stations is an impossibility. The money for expensive installations does not exist, and the constant necessary supervision could only be applied through the agency of ignorant, low-caste natives. Where such conditions obtain, the only resource is to fall back on a hand-and-cart method of removal, recognize its inevitable dangers, and make the best of the situation. This is just one of those positions where it is essential to remember that sanitation is merely adapting oneself to one's surroundings. I should like to add one word of warning here as to the danger of introducing civilized methods of hygiene to a population that is unaccustomed to or does not want them, or in places where the actual daily detail must be carried out by cheap native labour. In such cases the old proverb, *Corruptio optimi pessima*, is more than ever true. It is often better, retrograde though the step may appear, to keep to the ancient ways.

Accepting, therefore, the conclusion that, under circumstances such as I have detailed, we are forced to abandon the more efficient and scientific method of water carriage, and rely on a hand-and-cart system of removal, I propose to describe at some length the essential points of this last method, and in doing so shall keep in my mind chiefly the conditions as they have to be dealt with in the great majority of Indian stations, since not only am I better acquainted personally with these conditions, but, as far as the army medical officer is concerned, they constitute a problem with which he must inevitably find himself sooner or later brought face to face.

The essential distinction between any such system of removal and a water-carriage system is that removal has to be carried out by hand and periodically, instead of being automatic and immediate. For a longer or shorter period, therefore, the excreta, liquid and solid, have to be detained in the more or less immediate vicinity of the dwelling. The entire success of a conservancy system depends on the efficiency with which it prevents, during this period of inevitable retention, (1) the occurrence of nuisance, and (2) the passage of possibly infective particles of the excreta from the receptacle in which they are contained pending removal, to the air, water, or food supplies of the community. The

prevention of nuisance is, of course, essentially a question of deodorization, and this, again, is largely a question of occlusion and distance. In the case of barracks, therefore, latrines should, to begin with, be at a good distance from the barrack bungalows, and the receptacles should be closed. There is little difficulty about the former, and I would feel inclined to lay down 50 yards as a reasonable distance. The closing of the receptacles is another matter, and here we are brought up against one of the great difficulties of all such systems. Obviously, the excreta must be kept, pending removal, either in the receptacle into which they are passed by the man, or transferred into another. In the former case we have at once the difficulty of closing the receptacle, which may need to be used by other men ; in the second we have to recognize the emptying of excreta from one receptacle to another, with all its attendant dangers of spillage, difficulty of cleaning, etc. Personally, I consider the danger of the latter procedure greater than the risk of nuisance attached to the first, and I hold strongly that the excreta should remain in the receptacle into which they are first passed until final removal. It is possible to have automatically closing flap covers to the latrine seats, though I have but little faith in these, or, rather, a well-grounded trust in the capacity of the private soldier to circumvent any such apparatus if it is likely to be in any way irksome to him. If any further deodorant action is required, I would trust to the use of chloride of lime, or an emulsion of crude carbolic acid, or other similar compound, sprinkled freely about the latrine. The difficulty in respect of nuisance, then, can be overcome in the above manner. We have now to consider the danger. This, of course, consists in the fact that there is always a possibility of one or more men in a unit being a " carrier " of the germ of enteric fever or some other of the so-called intestinal diseases, and therefore a further possibility of the germs passed by him obtaining access to the air, water, or food supplies of his comrades. This can only happen if some means of transport are provided, and there are, as far as I know, only two methods in which this can be furnished. The germ must be carried either on the person of the individual who happens to be in the habit of passing it, or by flies. The former is,

of course, a very distinct danger, and one that it is difficult to guard against if the man is engaged in the cookhouse, or is otherwise concerned in the preparation of his comrade's food. This point will be again referred to under Enteric Fever. As regards the house-fly, which I consider the greatest danger, most elaborate steps must be taken. In the first place the latrine seat should be closed in round the receptacle, so as to afford as little facility for the access of the fly to its contents as possible. The only difficulty here, again, will be in the case of the lid, and it may be necessary to place a man on duty in the latrine to see that the lids are kept closed after use. I do not place much reliance, however, on any mere mechanical appliance as regards the exclusion of so pertinacious an insect as that which we are now considering. The only measure on which I do place reliance is the use of some strong-smelling chemical which shall be obnoxious to the fly. This must be used freely on the floors and walls of the latrine, and the wooden seats must also be thoroughly scrubbed with it. The under-surface of these seats should also be tarred once or twice a week with the same object. I know by experience that, using such precautions, it is possible to keep flies out of latrines without any mechanical appliances, and I have too little faith in such appliances to trust to them alone. If possible, I would have both, since two strings are better than one ; but if only one is possible, then I should rely on the strong-smelling chemical as the most efficacious method. Whatever means are used, of one thing I am most sure : the efficiency of any method of conservancy at this stage is in inverse ratio to the number of flies in the latrines ; these pests are not only themselves the great danger, they are also the most obvious evidence of its existence.

Distance has, of course, a distinct importance as regards the danger from the excreta, in addition to its importance as regards nuisance. No latrine should, in my opinion, be within 100 yards of any kitchen, and the greater the distance the better. The recklessness—one can hardly use any other word—with which these structures were at one period distributed throughout barracks is hardly conceivable nowadays. There is at present in the museum of the Royal Army Medical College a notice-board from the hospital at

Ahmednagar inscribed with the following legend : "No. 23. Cookhouse, Lavatory, and Privy," showing that all these three offices were combined in one structure. And though this is an extreme, it is by no means a solitary instance, of such ineptitude in design.

Structure of Latrines.—It was the custom at one time in India to build these of brickwork, mud plastered, the floors being also of brickwork, though more frequently of earth, possessing in either case numerous chinks and crevices. All latrines should be constructed of impervious material, either metal, or of some of the modern patent fireproof building compositions. They should be built with double walls and roofs to keep out the heat, and the materials assembled in such manner that the entire structure can be dismantled and transported to another position if necessary. The floor should be of concrete or good masonry, if procurable. Where this is impossible, I would rely on an earthen floor prepared with kerosene oil. This is infinitely better than brickwork, which always wears unevenly, and affords numerous crevices for the accumulation of filth. The seats should be solid wooden slabs resting on iron brackets, but not fastened down : the receptaces, large metal buckets of the dimensions of those in use in standing camps in England. The small earthenware pan, or *gumlah*, is not, I consider, permissible. These receptacles should fit closely to the seats, and be kept in position by guides fixed either to the under-surface of the seat or built into the floor. They should be removed through an aperture at the back of the seat closed ordinarily by a heavy flap door. Whether this is to be done once or twice a day must depend on the ultimate arrangements for removal to the disposal-ground. If possible, this should be carried out twice in the twenty-four hours, but always by daylight : this last point is essential. The dangers of a hand-and-cart removal system are multiplied tenfold if it is carried out in the dark ; and as the only objections to a daylight method are sentimental, they should be overridden. Immediately after removal from beneath the seats, the pails should be closed by means of heavy metal lids fastened down by a solid clamp, and these lids should not be again removed from the pails until they are about to be emptied at the disposal-ground.

Details are, however, immaterial. The object to be constantly kept in mind is that no loophole must be allowed for any particle of potentially infective matter to escape from the pail until it is finally emptied at the trenches or pits for disposal. Such escape is effected either by the agency of flies which have obtained access to the excreta while the pail is under the seat in the latrines, or as the result of splashing during the subsequent inevitable moving about of this receptacle. The first essential is to keep the flies out of the latrines ; the next, to move the pail as little as possible until it is hermetically covered ; and, lastly, never to move it about at all except during the hours of daylight. If any accidental splashing should occur, it can then be at once detected, and suitable steps be taken to counteract the possible danger.

A greater difficulty than that presented by the removal of the solid excreta is presented by the urine. In the first place, the bulk is enormously greater ; in the second, there is far more danger of splashing during removal ; and in the third, and most important of all, it is almost impossible to induce men to look on urine as being so dangerous a substance as the solid excreta. The best pattern of urinal is a trough discharging into a tub or similar receptacle. This latter should be removed as it stands to the disposal-ground or to a central depot, due care being taken, as in the case of the fæces, to prevent access of flies or splashing. The building in which the trough is placed should be constructed of materials similar to those already mentioned under the head of Latrines, the floor being of impermeable material, or else of earth hardened by the application of kerosene oil. Of the two, I prefer the latter, since it is difficult to get any impermeable flooring to withstand evenly the assaults of the ammunition-boot, and an oiled earthen floor is more easily kept in order and repaired than a chipped or worn concrete floor. Where good paving-stones are available, these may be used. The so-called " Cuddapah slabs " are excellent for this purpose. The trough may be of metal or earthenware, with, if possible, a good glaze. Glazed or not, it should be constantly oiled to facilitate the flow of the urine. I have seen many different forms of trough, but I have never yet seen one which would with certainty prevent

spilling on the floor, the result of carelessness, sometimes of drunkenness. It is, therefore, of the greatest importance to keep flies out of urinals, and the use of chloride of lime or some other deodorant is advisable. The receptacle into which the trough discharges should be covered, and I know no better method of doing this than to use a conical wire or wicker basket fitting on to the rim. This basket should be filled with pieces of wood charcoal well sprinkled with mineral oil. This will serve to keep away flies, and at the end of the period of use the charcoal can be burnt and re-used. The receptacle should be of considerable size, and, in my opinion, supported on wheels, so that it can be removed as it stands without any emptying or unnecessary handling, and it should, of course, be provided with a lid. The danger of splashing is great, and this can be obviated in part by using large receptacles, so that they shall never be more than three-parts full, and also by floating leaves or grass on the surface of the fluid. This very simple contrivance is most efficacious in this direction. The urine must eventually be removed to the disposal-ground, and there is a great difficulty here. Either each individual receptacle must travel the whole way, or there must be some central depot where the smaller tubs may be emptied into larger tanks. The first method multiplies transport enormously; the second means splashing. The removal of urine is, in fact, a very serious problem. If we place the average excretion at 2 pints per man, the total weight of fluid that has to be transported in respect of this excretion in the case of an infantry battalion at full strength is well over a ton, with a total bulk of 40 cubic feet. Perhaps some form of travelling vacuum tank would be the most satisfactory apparatus for this purpose. If we remember how comparatively easy it is for a negligent or lazy sweeper to get rid of his load in any convenient ditch, it is allowable to maintain a certain amount of scepticism as to the thoroughness with which this amount of fluid is on occasion removed from the vicinity of barracks, especially when this operation is carried out by night in a cart of the usual pattern.

The removal of excreta from barracks is, I consider, the most important part of the daily sanitary routine in an

Indian station. No mechanical appliances can possibly insure its being carried out in such a manner as absolutely to preclude all danger. It is therefore essential that the details of latrine and urinal management should be entrusted to some reliable person, private or non-commissioned officer, and not left to the mercy of the low-caste native sweeper and his ideas of what constitutes efficient conservancy. The duty need not be by any means unbearably unpleasant, unless the latrines and urinals are allowed to get into bad order. There is no reason why this duty should be given to one selected man—in fact, it would be better if all the men took their turn at it, since all are equally interested in its proper performance. Such a method, too, deprives the selection of a man for this duty of any invidious appearance.

In addition, company officers should be made to realize the essential importance of this branch of sanitation. Under a well-organized regimental system, there need be no difficulty in maintaining satisfactory conservancy with a minimum of offence to any individual. If it is left to the sweepers, there will be no proper conservancy, and a maximum amount of nuisance to everybody will inevitably result.

Difficult as the problem of removal of excreta from barracks undoubtedly is, it is simplicity itself when compared with that which confronts us when we have to deal with the bungalows occupied by officers. A short description of the ordinary bungalow and its surroundings is advisable here for the benefit of those officers who have not yet made acquaintance with Indian surroundings.

In the first place, the bungalow itself is a large one-storied building, consisting of a larger or smaller number of sitting and bed rooms. The chief peculiarity which distinguishes it from an English house is the fact that there is no general closet, each bedroom being provided with a small annexe or bathroom in which a bath and commode are placed. The excreta are removed from this room by a special low-caste servant, the sweeper, and by him deposited in a metal receptacle placed in an outhouse in the compound, which also officiates as the servants' latrine. The distance at which this is situated from the bungalow depends entirely

on the size of the compound, and this, again, usually on the size of the bungalow. Where a large bungalow is situated close to a small one, it is quite possible that the native latrines of the two compounds may be in extremely close proximity to the latter dwelling, and this condition of affairs is by no means exceptional. The occupants of the bungalow itself are probably from one to four in number, not often as many as six; but the number of natives inhabiting the compound is limited only by the number of relatives which the caprice of the domestics or the laxity of the masters permits to reside in the servants' quarters. In addition to the human population, there are, as a rule, one or more ponies or horses stabled in the compound. Obviously, therefore, we have in any cantonment a large number of isolated filth-depots, each of which is a potential cause of danger to the community. The larger the cantonment and the more crowded the bungalows, the greater the danger.

The supervision of these numerous scattered native latrines is a task of the greatest difficulty. Nominally, it is the duty of the cantonment magistrate and his staff, but in reality it is impossible for any one man, however energetic, to carry out this duty. It is essentially incumbent on every occupier of a bungalow to look after the latrine in his own compound, and, indeed, the general conservancy of that area. That the former task is an unpleasant one I readily admit, but the more efficiently it is performed the less unpleasant it becomes. A daily visit to the latrine need not take any long time, and can conveniently follow the daily visit to the stable, which is part of the ordinary daily ritual. The use of strong deodorants—*e.g.*, chloride of lime or crude carbolic acid—is advisable, not with any idea of destroying possible infection, but merely with that of driving away flies. (I use the word "deodorant," because the killing of smells is one, though the least important, of the objects of the use of these substances, and partly also because I am loath to coin so hideous a word as "muscifuge," which would more accurately signify their real intention.) At the same time, the owner should see that a proper receptacle exists in the latrine, and that the lid is not only in good repair, but in its proper place—namely, on the top

of the receptacle, and not, as is more usual, propped against the side of it.

Whilst on this question of native latrines, I should like to say just a few words about that humble but absolutely necessary domestic, the native sweeper. This man is a low-caste Hindoo, using this word in a wide sense, or else a low-class Mohammedan, and his position is best described in the phrase originally attributable, I believe, to the late Miss Nightingale—namely, "a human drain-pipe." This is, indeed, his proper function, and should be his only function. This principle is not, however, always observed, especially in the case of British units lately arrived from home. I have in my mind a distinguished infantry battalion, not long in the country, in which every table servant had the designation "sweeper" written plainly on his face. I know another instance in which two cases of enteric fever occurred amongst some young officers which were traced with great probability to the fact that the early-morning tea was brought from the mess by the bungalow sweeper. Now, there is not the slightest use mincing words in a case like this. To allow a sweeper to come into contact in any way, however indirect, with one's food is as nasty—there is no other word suitable—as to eat one's meals in a water-closet. And though this is not a sanitary aspect of the subject, I may add that the better class of native servant looks on any man who allows such contact knowingly to occur much in the same way as we should look on one who was addicted to the other objectionable practice. It is the duty of any medical officer in charge of a newly-arrived battalion to impress on the officers of that unit the danger to which such laxity exposes those who are guilty of it.

The removal of excreta from the compound latrine is a matter with which the cantonment magistrate is concerned. Here, again, the difficulties are enormous, and they are multiplied a hundredfold when removal is carried out by night. Daylight removal is the first essential towards efficiency in this respect.

Whether we are dealing with barracks or private bungalows, the ultimate removal must be carried out by cart, except in hill-stations. I have no doubt in my own mind as to the pattern of cart that is the best for this purpose.

In the first place, there must be no emptying of receptacles in barracks, and therefore any tank pattern of cart stands condemned. The cart should be a lorry, with the centre rather higher than the sides, so that the latrine receptacles may be stacked on it in two layers, or rather at two levels. This cart should be solidly built, with stout wheels, and should be dragged by horse-draught. Such a cart was introduced at Quetta in 1899, and acted admirably. Removal should be by regular roads, and at certain definite hours. Carts should not be allowed to wander erratically up any back-lane, lurching from one rut into another, but all should be confined to good metalled roads. Horse-draught is not essential, though infinitely better than bullock-draught, because quicker, and in the long-run, I believe, cheaper. I need hardly say that motor-draught would be preferable to either. The distance to which removal should be effected is important, and the only limitation is the expense. It will depend partly on the number of times at which removal is made during the twenty-four hours, partly on the establishment of carts maintained, and the pace at which the draught animal used is capable of travelling. The ideal, in my opinion, is attained by the use of horse-draught lorries for removal to a depot close to, but to leeward of cantonments, using a light railway for the rest of the distance. The receptacles should be transferred direct from the lorries to trucks of any suitable construction on the rails. With some such system removal to three or four miles should not be impossible, and if that is effected, the subsequent question of disposal is one of comparatively less urgency.

From beginning to end the whole efficiency of any conservancy system in Indian cantonments depends entirely on supervision by responsible Europeans. The native does not, and will not, understand the importance of the subject. Whether as a result of custom, or education, or merely because of Oriental fatalism, he will not of his own " mere motion " pay that attention to detail which is absolutely essential. The average British officer and soldier, accustomed all his life to have removal carried out for him, and to have his responsibility in this matter limited to the pulling of a handle, takes time to realize the alteration in

his surroundings in this respect. The old tag, *Cœlum non animum*, is as true with regard to sewage removal as with regard to any other ingrained habit.

The difficulties of such a system are, in fact, so great, and the loopholes for danger so innumerable, that I am steadily coming to the conclusion that the solution of the problem lies in some method of incineration *in situ*, whereby all the difficulties and nine-tenths of the danger are avoided. The consideration of this, however, I defer till I come to the question of disposal.

CHAPTER XIII

DISPOSAL OF WASTE MATTERS

In discussing the question of the disposal of waste matters it is necessary to remember the division of these matters —to which reference has been made when considering their removal—into two classes—namely, those which can only produce a nuisance, and those which in addition are the possible vehicles of specific infectious disease.

The meaning which we attach to the word "disposal" varies with the class of waste matter which we happen to be at the time considering. The first class, which produce merely a nuisance, do so because they are in large part organic in their nature and therefore putrescible. This quality of putrescibility persists until all the organic matter is completely oxidized, and therefore the disposal of waste matters in so far as they are the causes of nuisance, consists simply in their oxidation, whether rapidly by fire, or more slowly by natural biological processes. The second class, in addition to being possibly the cause of nuisance, are actually dangerous on account of the fact that they may contain the germs of specific disease, and disposal in their case should, strictly speaking, connote the destruction of these disease germs, in addition to the oxidation of the accompanying dead organic matter. In practice in this country this distinction is not observed except in cases where specific intestinal disease is known to exist. This is partly because of the comparative rarity of diseases, such as enteric fever, cholera, and dysentery, and partly because, owing to the great efficiency of modern systems of drainage, the danger is at once removed to a safe distance. Where water carriage is impossible, and where intestinal diseases are comparatively common, the distinction is a very necessary

and important one, which needs to be kept constantly in mind.

It is important to remember, too, that these two methods of disposal—oxidation, which prevents nuisance, and sterilization, which destroys danger, are absolutely unconnected with each other, since either can be accomplished successfully and completely without the other being even attempted. Thus, for instance, it is possible to oxidize completely all the sewage from a large country house by means of a very simple biological installation situated in the grounds, in such a manner that the effluent may be discharged into any convenient watercourse without causing a nuisance. Supposing, however, a case of enteric fever should occur in the house in question, it would, in the present state of our knowledge, at least be impossible to guarantee that the specific poison, supposing it to get access to the sewage, would be with certainty destroyed by passage through the biological installation, whatever the character of this might be. In such a case the distinction between the two lines of disposal would be at once recognized and acted on. Again, it would be simple enough to sterilize even a considerable bulk of sewage either by boiling, or, in theory at least, by chemicals, without in any way interfering with its putrescibility. The danger would be removed, but the power of causing a nuisance would not be affected, and oxidation would still have to come into play to effect complete disposal.

Where a water-carriage system of removal exists, the potentially dangerous matters are mixed up with a large bulk of other matters which can do no more than cause a nuisance, and, in theory at least, the whole mass must be looked on as equally dangerous. In practice, however, as already pointed out, the danger is so comparatively small and the nuisance so very obvious that attention is entirely directed to the prevention of the latter.

Where a water-carriage system does not exist, the mixture of the different classes of waste matters does not occur, the dangerous being kept strictly separate from those that are merely troublesome. Disposal, therefore, can now be carried out in a much more scientific manner, each class being dealt with in a different way, according to its peculiar

attributes. I have little hesitation, therefore, in saying that on purely theoretical grounds alone it would be correct practice to sterilize *in situ* all excreta, where these have to be removed by a hand-and-cart system ; even if this latter process were free from all the difficulties which I have attempted to describe in the last chapter, I should prefer, personally, that method of sterilization which includes complete oxidation—in one word, incineration. Under the circumstances as they meet us in military practice, especially in India, the argument for some such method of sterilization *in situ* is enormously strengthened.

In the first place, however, I will discuss the disposal of sewage as ordinarily understood in this country, where all the used water of the community is removed by the one process. The subject is an extremely complex one in civil practice, since it is complicated by the addition to the sewage of various forms of trade waste, which interfere with the biological processes employed for the oxidation of the sewage. In military practice, however, these do not occur, and I shall confine myself to dealing with the problem in its simplest form, that of the disposal of a purely domestic sewage, containing human excreta, together with kitchen and wash-house slops. The main point to keep in mind throughout the study of every scheme of disposal is the fact that disposal means oxidation, and that every step which assists oxidation is a step forward, whilst every measure that retards or impedes that process is retrograde. This oxidation occurs normally in the case of all organic dead matter, through the agency of minute forms of animal and vegetable life, utilizing the oxygen of the atmosphere. Unless assisted artificially, this oxidation cannot ordinarily be effected sufficiently rapidly to prevent putrefaction, and the whole aim of modern methods of sewage disposal is to supply that artificial assistance. Taking any putrescible fluid, it is obvious that the simplest way to procure oxidation, on the lines above laid down, is to bring it into contact with the micro-organisms in extremely thin layers, so that as large a surface and as small a total bulk of sewage shall be exposed to the oxygen available. Such an arrangement could be readily supplied by permitting the sewage to flow over any broad flat surface in a thin sheet, but obviously

this would demand an enormous extent of ground. A more practicable method is to construct a heap of solid material as a framework on which bacteria, etc., can grow, and to allow the sewage to flow through the interstices of this, and, in fact, this method is one of those most frequently adopted. Clearly, however, for such an installation to work satisfactorily the fluid must be as limpid and as free from suspended matters as possible, since these, if present in large amount, will inevitably block the pores or interstices of the framework, and impede the flow of the fluid. The difficulty is increased if the suspended matters be themselves putrescible, since they will absorb a certain amount of oxygen, and also undergo putrefaction in the substance of the framework, and thereby produce a nuisance. Now, in the case even of a domestic sewage we have a certain amount of suspended matter, both inorganic and organic, present, and before the sewage can be satisfactorily oxidized it is necessary in general to get rid of this. In the case of heavy suspended matters, such as road grit or sand, these are best separated by the intercalation in the flow of the sewer of a detritus or grit chamber, which intercepts all non-floating heavy débris. At the same time a screen or grating holds back the coarse floating matters, pieces of paper, orange peel, corks, fragments of cloth, and so on, that may be present in the sewage. In addition to these gross particles, however, the sewage contains a large amount of fine suspended matter, and this also must be got rid of.

This may be done in one of three ways. The fine matter may either be allowed to sink to the bottom of the sewage, by simple sedimentation; thrown to the bottom as the result of adding certain chemical substances to the sewage—that is, by precipitation; or dissolved by biological action in a septic tank. In either of the first two processes we simply divide the sewage into two parts, one called the "sludge," containing almost all the solid matter, and part of the liquid, the other containing a very little solid matter, but the bulk of the fluid. Each of these has now to be disposed of separately. This problem of the disposal of sludge, however produced, is one which has given much trouble to local authorities. The difficulty consists in the fact that

we have an extremely bulky and very heavy mass of highly putrescible mud which must be oxidized, but which does not in any way lend itself to easy handling. Attempts have been made to compress the sludge into cakes, the expressed fluid being returned to the main mass of sewage, and the cakes sold as manure. This process has met with a certain amount of success, but owing to the large amount of grease present the manurial value of the sludge is not very high. Lately attempts have been made to recover the grease from the sludge, which is thereby improved as a manure, whilst at the same time the fats obtained have a very considerable market value. This process has met with a gratifying measure of success at Oldham, and is probably the most scientific method yet adopted. Incineration, deposition at sea, and other plans are practised at different places, but these are unremunerative, and in the case of the two just named seriously extravagant. The dissipation into the atmosphere, or the loss at sea, of large amounts of nitrogen is neither scientific nor business-like. The problem of sludge disposal has in the past presented so many difficulties that the idea that it would be possible to get rid of the substances which give rise to it by means of biological action was naturally received with great favour. The first practical application of the idea in this country was made at Exeter by Mr. Cameron, and undoubtedly it has there met with considerable success. In this, commonly called a "septic tank installation," the sewage, after rough straining and passage through a grit chamber, is led into a closed tank, the inflow and subsequent outflow taking place in such a manner as not to cause any disturbance of the surface. In the original plans the tank was completely closed in, all light and air being excluded, and the resulting gas was collected and utilized to light the works. In a very successful installation constructed by Mr. Carkeet James at Matunga near Bombay, the gas was made to drive a small engine, which pumped the effluent on to a high-level filter for further treatment. Subsequently, however, it was found that it was not necessary to close in the tank, and open tanks have been used in many places. Where such tanks work well they undoubtedly work extremely well. The organic solid matters are slowly liquefied by the

action of anaërobic bacteria, and all that remains in the tanks is a small amount of mineralized humus. On the other hand, they have, more often than not, failed to come up to expectations, producing merely a putrid effluent, deprived of its solids to no greater extent than can be achieved by simple sedimentation. The conditions necessary for success seem to include an accurate adjustment of the length of time that the sewage remains in the tank to its strength and composition. Unfortunately no one so far has been able to predicate with any accuracy in respect of any given sewage the period which it is necessary that it should spend in the tank. Clearly the size of the tank depends on this adjustment, and any mistake in construction must influence importantly the subsequent policy, if the expression may be used, of the tank. Any great changes in the amount of flow, or any liability to marked rushes of sewage at certain hours of the day, must obviously affect seriously the question of the installation of a septic tank. Any great increase in the amount will obviously dislocate timing, whilst sudden rushes will disturb the contents of the tank, and lead to equally sudden discharges of unevenly septicized sewage into the other parts of the installation. Briefly, then, the present position with regard to septic tanks seems to be that they act chiefly as sedimentation tanks, and that any biological solution of solid matters that may take place is an accidental advantage that cannot be counted on. Since the sludge difficulty cannot be positively excluded, it is obvious that for purely mechanical reasons, facility of cleaning, etc., it is better to construct these tanks without a roof.

After the sludge has been removed from the sewage, by whichever of the above methods may be selected, there still remains the comparatively clear putrescible fluid to be dealt with. The way is now, however, open to oxidation in the meshes of a solid framework in the manner to which I have already alluded.

This is carried out in one of two ways. In the first, the sewage is poured into a tank already filled with clinkers or other suitable material, and allowed to stand there for a longer or shorter period ; in the second, the sewage trickles slowly through a similar mass of material in a continuous,

unbroken flow. In either case a thick growth of organisms forms itself on the surfaces of the integral parts of the framework, and these affect the ultimate oxidation of the putrescible matters held in solution, and to a less extent in suspension, in the sewage. If the sewage is allowed to stand in a tank, the installation is termed a " contact bed " ; if it is permitted to trickle through continuously, it is called a " streaming or continuous filter."

A contact bed is a tank usually about 4 to 6 feet deep, filled with solid matters about 2 inches cube ; clinkers, saggers, road metal, or other convenient material being used. The selection of material depends entirely on the question of cheapness. If clinkers are available in the immediate neighbourhood for comparatively little cost, the fact that they are able to crumble easily, " degrade " in the technical expression, may be overlooked in view of their local cheapness. If material has to be brought from a distance, then it is essential that it should resist degradation, and thus postpone the day of reconstruction of the bed. It must be remembered that the material used acts, no matter what its nature, merely as a framework. Of itself it possesses no peculiar virtue beyond supplying a basis for the building up of the active purifying agent—in other words, for the bacterial coating which rapidly grows in its interstices.

A contact bed is worked on the following principle : The sewage, clarified if necessary, is poured on to the surface of the bed until the latter is full ; it is allowed to rest there for a fixed period of time, and then allowed to run off, after which the bed is left standing empty until again required.

The mechanism may be described as follows : The first effect of pouring the sewage on to the bed is to displace the air already entangled in the framework—a process which does not take place without a considerable amount of disturbance of the fragments of which it is composed—the greater in proportion as these last are lighter. During this process a certain amount of oxidation takes place as the air bubbles through the entering fluid. During the period of rest, while the bed is full of sewage, a certain amount of oxidation may take place near the surface of the bed, but in the depths there is probably no such action. On the contrary, a certain amount of anaërobic decomposition

occurs, more marked in the deepest parts, and proportionate in extent to the length of this period. There is also a certain amount of deposition of the very fine suspended matters still remaining in the sewage, and an extensive separation of colloid matters by adsorption to the material forming the framework. During the period occupied in emptying no chemical action of importance occurs, with the exception, perhaps, of some slight oxidation in the upper layers still in contact with the air. At the same time as the fluid is withdrawn there must be a certain amount of settling down of the framework, as a consequence of the replacement of the heavy fluid by the comparatively lighter air. This furthers the process of degradation. During the period when the bed is at rest empty, all the fine suspended matter left behind, the colloid matter adsorbed to the framework, and the fluid retained by capillary attraction are acted on vigorously by the bacterial flora of the bed. It is during this last period that the real work of the bed as an oxidizing agent is performed.

The successful working of a contact bed depends on a careful allocation of time to each of the four periods—filling, standing full, emptying, and standing empty—which have been already described As regards filling and emptying, it is clear that if these are carried out too rapidly the amount of resulting disturbance of the framework will be unduly great, and the consequent degradation of material unnecessarily large. At the same time, since these periods are unimportant, *qua* the oxidizing action of the bed, they should not be unduly prolonged. The amount of disturbance will naturally be greater in a deep than in a shallow bed for the same rate of flow ; therefore a broad, shallow bed presents advantages over a deeper bed with a smaller superficial area. The broad, shallow bed will at the same time expose a greater surface of sewage to oxidation than the deeper bed, and therefore presents a definite advantage in connection with the work of the standing-full period. This benefit is supplemented by the fact that there will be less anaërobic action in a shallow than in a deep bed, whilst the processes of deposition and adsorption will not be interfered with. The length of time allocated to the standing-full period should be long enough to permit of these last-named

processes being efficiently carried out, and at the same time not so long as to allow of any great amount of anaërobic action being effected in the depths of the bed. It should be recognized that the second, or standing-full, period is only, as it were, the handmaid to the fourth, or standing-empty, period, during which the chief work of the bed is performed. This last period should therefore be the longest of all. It is impossible to lay down an absolute rule, to be applicable to all cases, but in practice the length of time allocated to the different periods, beginning with that of filling, is about 1 : 2 to 1 : 4. Coming now to absolute figures, it is convenient, generally speaking, to give about one hour to each of the comparatively inactive periods of filling and emptying, with two hours for standing full and four hours for standing empty. It must be admitted that there is little or no strictly scientific basis for these actual figures, but in practice they have been found convenient, and may be remembered as a safe guiding rule. The timing is regulated in most cases by some form of automatic apparatus.

It is usual to arrange contact beds in series, the sewage passing from one to the next, and these are generally termed "primary," "secondary," and "tertiary" beds. The working, in theory and practice, is the same for all. I have ventured to summarize this question of the working of contact beds in the above fashion, without claiming that it says all there is to be said about these rather complex structures. The above theory appears to me to satisfy fairly well the facts as we know them, and agrees with actual experience.

A streaming filter differs from a contact bed in the fact that there is no variation in the flow of the sewage, which runs steadily through the solid framework of the filter. There are no retaining walls, except in so far as these are necessary to prevent the loose fragments of which the framework is composed falling away from each other. The most obvious difference between this arrangement and that of a contact bed is that, since the flow of the sewage is in no way interfered with, there is no force compelling this fluid to distribute itself evenly through the bulk of the framework. The sewage naturally trickles through the mass by the most direct route, and the great crux in all such installations is to insure by mechanical means that all parts of the frame-

work shall receive an equal supply of sewage. This is achieved by means of tipping trays and revolving sprinklers of numerous forms. Some of these are ingenious in the extreme—such, especially, as the reversible rollers of the Fiddian system—but it is unnecessary to go into detail as regards them. The important point to remember, I consider, is that whatever mechanical means are adopted, the process of distribution will be greatly assisted by increasing the depth of the filter at the expense of its superficial area. Theoretically, such an increase in depth need only be limited by the difficulty and expense of constructing sufficiently strong retaining walls, and by the crushing effect produced on the deeper parts of the framework by those above. In a properly constructed streaming filter the action should be purely one of oxidation, and continuous. Theoretically, therefore, a streaming filter is more efficacious than a contact bed, and the findings of the Sewage Commission are in support of this contention. Generally speaking, contact beds should be more satisfactory where the fall is comparatively slight, and where, accordingly, shallow beds would be more practicable from the constructional point of view. This advantage would be lost to a great extent if primary and secondary beds were needed. Contact beds are less likely to cause a nuisance, are said to be less likely to encourage the breeding of flies, and the effluent contains less suspended matter. On the other hand, filter beds are cheaper to construct, the material used need not be so fine, and there is no danger of silting up. They do not need remaking, and they are less sensitive to frost. In any particular case all the circumstances must be carefully considered before coming to a definite decision. For military use the filter is probably, in general, the most satisfactory installation.

Sewage may be disposed of by direct application to land, and this is still done in some places. Two main methods are resorted to—namely, broad irrigation and intermittent downward filtration. In the first named, which is also called "sewage farming," the sewage is poured on to land more or less continuously, with a view to utilizing its agricultural value. In the latter it is poured intermittently on to specially prepared and underdrained plots of soil, and the

oxidation is entrusted to the soil bacteria. In principle the two methods differ merely in the fact that the former uses the higher forms of vegetable life, which are suitable for the food of men and animals, and the latter relies on the humbler class of micro-organisms. I do not intend to enter into the details of the working of these systems, since the installation of either at the present day as a means of disposing of a crude sewage is unlikely. At the same time, it must be recognized that no system of sewage disposal which does not include the ultimate application of the purified effluent to land can be looked on as complete. The surroundings may be such as to prohibit this application, but where possible it should always be resorted to, not so much with a view to oxidizing the sewage (this should be already complete, or nearly so), as with the intention of utilizing the organic nitrogen therein contained. The careless squandering of fixed nitrogen into rivers or the sea, or its wasteful conversion into atmospheric nitrogen, is a scientific error of considerable magnitude.

Both contact beds and filters, though more especially the former, tend in course of time to get blocked up. In the former case this is in great part due to the degradation of the material composing the framework. In both forms of installation, however, there is a deposit of unoxidizable residue from the sewage, and also in the majority of cases an accumulation of more or less putrescent matter in the depths of the framework, the access of oxygen to which has for one reason or another been hindered. In such cases the beds need to be thrown out of work, and in the case of contact beds remade, to enable them to become efficient again. These difficulties are in part due to the comparatively small size of the interstitial spaces of the framework, which, again, is due to the small size of the particles of which it is composed. In order to avoid the necessity of remaking the beds, Mr. Dibdin introduced what are termed "slate beds." In principle these are merely contact beds, but constructed in a more systematic manner than those commonly in use. Instead of containing a mass of comparatively small particles arranged at random, the slate bed consists of layers of slate laid regularly one above the other, each layer being separated from those above and below by

means of slate blocks 1 or 2 inches in thickness, the latter being the size most commonly in use. Such a bed is filled and worked in precisely the same manner as a contact bed. The sewage, after being deprived of its gross solids, is run on to the surface of the uppermost layer of slate and gradually fills the bed. Owing to the great weight of the material, the forcing out of the contained air does not cause the disturbance of the framework, which occurs in the ordinary contact bed during this process.

The action of the bed is probably on the same lines as that of an ordinary contact bed. In course of time a certain amount of humus gets deposited on the layers of slate, and when desired this can be sluiced out with an ordinary hose-pipe. Owing to the large size of the interspaces, the sewage capacity of a slate bed is about twice that of a contact bed of the same dimensions. After treatment on a slate bed, the sewage has to be passed on to an ordinary contact bed. Undoubtedly the great use of these beds is to act as roughing beds. The large size of the interspaces enables them to deal with masses of organic matter of considerable size without getting blocked, and the access of oxygen to the interior of the bed is far less likely to be impeded than in the case of an ordinary bed. It is claimed for them that there is no anaërobic action at any time, but on *a priori* grounds it is probable that there is a certain amount in the depth of the bed during the period of "standing full." Within limits there is no harm in this, and I see no reason to fear that there need be any over-septicizing of the sewage, which is so apt to occur in a septic tank.

The disposal of sewage is, as has already been said, purely a matter of oxidation, and any step in a contrary direction is retrograde. This is in practice, however, impossible to avoid. If we could get the organic matter of which we have to dispose in such a fine state of mechanical subdivision that we had only to deal with single molecules of protein, and if we could bring these into close contact with aërobic bacteria in the presence of a free supply of oxygen, the process of oxidation would be rapid and continuous. In practice, however, we have to deal with mechanical aggregations of considerable size, each containing a large number of molecules. It is obvious that only those molecules which are

on the surface of any particular aggregation can be oxidized at once. If the masses of organic matter are of any considerable size, or if the free access of oxygen is for any particular reason impeded, then, instead of oxidation, there will be a certain amount of putrefactive decomposition; that is, the complex molecules of which the organic matter of the sewage is composed will be split up into smaller molecules, but without oxidation.

The comparatively small size of the interspaces in an ordinary contact bed or streaming filter naturally tends to increase the likelihood of blocking, and of resultant impediment to the free access of oxygen, and accidents of this nature are of constant occurrence, and inevitable. That is to say, that in no case can we definitely say of either installation that oxidation is the only process that is going on in the depths of the framework. Here and there, in isolated areas small or large, anaërobic action is always taking place. If it is small in amount, no notice need be taken of it, as the resultant products of putrefaction are gradually washed into the main flow of sewage and oxidized.

As the age of the installation increases, such accidents become more frequent of occurrence, partly owing to the gradual mechanical blocking of the interstices of the framework by bacterial growth and inorganic débris, and these gradually lead to the necessity of an overhaul of the installation. Obviously, the larger the interspaces in the framework, the less likely are such accidents to occur, and the less likely is it that the access of oxygen shall be impeded. No arrangement of this nature can, however, get over the difficulty that arises from the presence of large masses of organic matter—as, for instance, lumps of disintegrated fæces. Anaërobic decomposition will occur in the centre of such a mass, whatever the pattern of the installation. With the small interstices of the ordinary contact bed we get the risk of blocking, which aggravates the nuisance; with the large interstices of the slate bed this is avoided, and the much freer access of air naturally accelerates oxidation.

The size of the interspaces in a slate bed enables this pattern to deal more easily with an irregular flow of sewage, whether this irregularity affects quantity or quality, than either a contact bed or a streaming filter, and therefore such

an installation may be used for the purpose of standardizing the flow of sewage, and thus facilitating its subsequent treatment.

Since the ultimate fate of all organic matter is oxidation, and since the object of all disposal systems is to effect this as perfectly as possible, it is obvious that the only test of the efficiency of an installation is the extent to which it oxidizes the sewage passed through it. A sewage that is completely oxidized is completely disposed of, as far as biological methods can dispose of it, and it does not appear to me that any other criterion, such as the total amount of nitrogen present, is of the slightest value. For practical purposes outside the laboratory, one of the best tests of an oxidized effluent is the presence of chlorophyll-bearing plants. If these can grow in the sewage, there can be very slight demand for oxygen on the part of the organic matter in that fluid, and such an effluent can safely be discharged into a river or stream, as far as danger of nuisance is concerned. If, instead of such green plants, a dirty grey flocculent growth is seen, then the sewage is insufficiently oxidized, and the installation inefficient.

Since the disposal of sewage is a biological process, there can clearly be no quantitative bacterial test for sewage. It is perfectly immaterial from a public health point of view whether a sewage which is completely oxidized contains 100 or 1,000,000 bacteria in each hundredth of a cubic centimetre. A qualitative test is equally difficult. The bacillus of typhoid has never, so far as I know, been isolated from a sewage effluent, though perhaps improved technique may in time achieve this. At present, the only qualitative test that we could apply would be that for the *Bacillus coli*, which, of course, is useless, since this particular bacillus is the one of all others which must inevitably be present in a sewage. Even, however, if we were able to demonstrate the presence of specific disease germs in the sewage, this would not necessarily point to any inefficiency in the disposal installation. Biological installations are concerned with the disposal of sewage only from the point of view of the prevention of nuisance, not from that of the prevention of specific disease, and the only test of their efficiency is the extent to which they solve the former of these two problems.

Disposal of Sewage from Barracks.—Barrack sewage differs in several respects from municipal sewage. In the first place, it is purely domestic in its nature ; in the second, it is extremely intermittent in its flow. During the afternoon hours and in the night there is hardly a trickle of fluid in the drains, whilst there is a great rush in the forenoon, and another, though less marked in amount, in the evening. As regards mechanical composition, the sewage from a barrack contains a large amount of unaltered fæcal matter. This is due to the comparatively short run of drain between the barracks and the disposal works. Lastly, especially in the case of cavalry and artillery, there is a relatively large admixture of stable drainage in the sewage. The irregularity of the flow militates against the use of septic tanks or contact beds, and to a less extent against that of streaming filters, unless some method of standardizing the strength and flow of the sewage is adopted. The presence of large masses of non-disintegrated fæces is also a cause of difficulty in the case of beds of any kind.

The difficulty with regard to stable drainage consists partly in the presence of a large amount of hippuric acid, which rapidly becomes oxidized into benzoic acid, and exercises an inhibitory influence on the biological process, and partly on the large amount of cellulose derived from the litter. This latter clogs the pores of the filtering framework, and is more productive of nuisance than any animal organic matter. Personally, I consider Dibdin's slate bed as the most hopeful of all installations for military purposes. It is less liable to clogging, and can be used to standardize the irregular flow of the sewage before it is passed on to contact beds or filters as may best suit the circumstances of the case. The disposal of barrack sewage presents many difficulties peculiar to the task itself, and those who have had the most experience of it will always be the last to dogmatize about it. Each individual case must be dealt with on its own individual merits.

The disposal of waste matters in the absence of a water-carriage method of removal is a question of considerable complexity, since each particular class of waste matter has to be considered separately.

The excreta can be disposed of either by a biological in-

stallation, by burial in the earth, or by incineration. Of these three, the first two are practically identical in principle, since in both biological action is involved. They also both necessitate removal to a considerable distance, whereas incineration can be successfully carried out *in situ*. Biological installations have been tried in India, but so far without very striking success. The difficulty lies largely in the composition of the sewage or rather night-soil. This is, of course, highly concentrated, and contains a large amount of non-disintegrated fæces, differing in both these respects from any civilian sewage in this country, and in the former, at least, and to a certain degree in the latter, from a barrack sewage. The difficulty of concentration can be got over by dilution with water at the site of the works, using for this purpose the water which should in any case be laid on for cleansing the buckets. To approximate in any degree to an English sewage it would be necessary to supply at least 15 gallons of water per head of the population concerned—a quantity which in India (and I have that country chiefly in mind in this section) is a serious matter. This water has of necessity to be additional to that already supplied in the station for ablution, etc., which cannot for obvious reasons be carried to the necessary distance in the absence of a drainage system. The water-supply of the station must, therefore, be increased by one-half on this account alone. Given this water, it is possible to get over the difficulty presented by the non-disintegrated character of the fæcal masses by means of a mixing tank. A scheme of this nature introduced at Maymyo, in Upper Burma, was distinctly successful. In this an open tank was constructed, into which the contents of the buckets were emptied, the latter being inverted over a powerful jet of water. When the tank was full, the contents were allowed to pass into a septic tank, both dilution and disintegration being thus effected.

The subsequent disposal, after thorough mixing and disintegration, can be carried out either by means of septic tanks, contact beds, or streaming filters, or a combination of these. Difficulties will arise in detail from the accidents of climate. Thus, the intense heat and drought of the summer months in the Punjab do not favour biological

processes, whilst the torrential downpour of the rainy months would affect the ultimate disposal of the effluent. All such difficulties are, however, only made to be overcome, and they can undoubtedly be overcome. They must, however, be expected, and, above all, not minimized in anticipation.

Disposal by direct application to land has been carried out for years by the Allahabad system of burial in shallow trenches. The theory of this method is the intimate admixture of the excreta with the superficial, biologically active, layers of the soil. As originally devised, the method satisfied the conditions but imperfectly, but the improvements introduced by Colonel Thornhill, of the Indian Army, were undoubtedly a great advance in technique. In this improved system it was intended that the excreta should be spread out in a thin layer in a shallow trench or pan, the floor of which was covered with loose earth, and then covered with a sheet of pulverized earth. The result was that the excreta were, supposing the details of the system to be carefully carried out, thoroughly mixed with the pulverized earth, and under ordinary circumstances oxidation progressed with great rapidity. The method demands careful working and constant European supervision to insure its being successful. Where these are supplied, success is, if not insured, at least in the great majority of cases achieved. On the other hand, without European supervision failure is an almost absolute certainty, and this is undoubtedly the weak point in the system. There is no need to blink matters. It takes a very high sense of duty to support the average British officer in a visit to the filth trenches in the early morning on a hot-weather day. As long as he is feeling well the achievement is possible, but any slight hepatic derangement renders it for nine men out of ten a veritable deed of heroism. A system which depends so importantly on the personal factor is inherently weak in practice, however scientific in theory. On the other hand, it cannot be denied that a biological system is also to a great extent dependent on European supervision. In the trenching method the native labourer is, after all, carrying out an operation with which he is perfectly familiar. He may not always perform his functions conscientiously, but at least he has nothing to learn, and under a strong master

he will probably keep up to a fair standard of efficiency. In a biological system all is strange, and though there is comparatively little to be done, still that little has to be taught, and taught as well as supervised, by a British officer.

In short, no disposal system with which I am acquainted can be carried out in an Indian cantonment without European supervision. It cannot be left, as it can in England, to " run itself " under the superintendence of an unskilled labourer, with an occasional visit from a skilled subordinate health official. The choice between one system and another, whether it shall be a biological installation, strictly so called, or an earth-burial method, which is, in fact, as much biological in principle as the other, must depend on local circumstances. It would be Utopian to suppose that whichever is chosen it can be left to look after itself. Success can only be insured by unremitting attention on the part of the municipal authority—in other words, the cantonment magistrate and the sanitary officer. The slightest relaxation of vigilance, however intelligible on the grounds of natural human weakness, means failure.

Such being the case, I consider that the ideal method of disposal in barracks in India is incineration *in situ*. My reasons for coming to this conclusion are partly the inevitable dangers of removal inherent in any hand-and-cart system, and partly the difficulties in the way of disposal already just alluded to. It must be remembered, too, that in India—and the same is true of all tropical stations—intestinal diseases are of much greater importance than in the British Isles. The weak point of the European in India is his intestinal tract, and disposal must therefore recognize the possible danger as greater than the certain nuisance, and aim first at counteracting the former. It is unnecessary to do more than refer to the difficulties attendant on removal when this is carried out by cart and hand, and the numerous inevitable loopholes which this furnishes for the passage of specific germs from the excreta to the air, water, and food supplies of the community. Any method which can at the same time eliminate these dangers, and do away with the problems attendant on disposal, must necessarily possess strong claims to recognition. Incineration *in situ*—that is, in the actual latrines—seems to me to solve the problem in

both directions. It has been proved several times over that this can be done without nuisance, using more or less improvised methods. Accounts have appeared of several of these from time to time in the *Journal of the Royal Army Medical Corps*, and I do not propose in this book to enter into details of apparatus. It is fairly clear, however, that if it is possible with improvised apparatus, it should be comparatively easy if some scientific incinerator were introduced. It might be necessary to use some additional fuel, and this is at hand in the ubiquitous kerosene oil of Oriental commerce, any extra expenditure being more than met from the saving in native establishment, conservancy drivers, *bildars*, etc.

The disposal of urine must be carried out by the same process as that used for the disposal of excreta. Supposing incineration to be resorted to, some form of boiler must be attached for the evaporation of the urine. A permanent difficulty is always attached to the disposal of cook-house slops and rubbish. As regards the latter, they should never if possible, be allowed to leave the kitchen. There should be no difficulty in destroying a great deal, if not all, the potato-peelings and similar vegetable débris on the hearth at the conclusion of the day's work. So much as cannot be thus disposed of should be sprinkled with kerosene oil and burnt—in the words of Major Dalgetty, "*Quam primum*, and that *peremptorie* "—in some convenient incinerator.

Kitchen slops present a great difficulty in consequence of the large amount of fluid grease, which does not, during many months in the year, at least in tropical climates, solidify and facilitate separation from the rest of the fluid. The difficulty is accentuated by the fact that, if cleanliness is encouraged inside the kitchen, in the matter especially of pots and pans, the amount of slops that have afterwards to be disposed of is proportionately increased. Pending removal, these slops must be protected from flies, and this can be done by allowing the discharge-pipe leading from the scullery sink to discharge over a tray filled with charcoal sprinkled with kerosene oil and fitted on to the receptacle as in the case of the urinals already described (see p. 219). In the colder months this arrangement will also act as a grease-trap, and thus assist in solving that difficulty. The

slops must eventually be disposed of by burial. They must not merely be poured into a pit, but on to a prepared pan in the earth, and then covered over.

Waste-water from ablution wash-houses must be disposed of by irrigation. It is out of the question to carry away the ablution water of 1,000 or even of 100 men in a climate where personal cleanliness is of such paramount importance, as in most of our foreign stations abroad. Such irrigation must be systematic, and the water utilized for growing plants—*e.g.*, lucerne grass, bananas, etc. If care be not exercised, there may be danger of encouraging the breeding of mosquitoes. This method of irrigation disposal is not always easy, but in my experience it is nowhere—in India, at least—impossible.

The disposal of waste matters, in the absence of a water-carriage system of removal, must always be fraught with difficulty, and always present the sanitary officer with one of the most difficult problems that he has to face. Whatever can be burnt should be burnt, and burnt at once *in situ*. A certain amount of nuisance may be expected from smoke, but this must be put up with. Whatever the system adopted, success can only be insured at the price of incessant, unwearying supervision by the medical and sanitary officers immediately responsible. Here more emphatically, if possible, than anywhere else there is no royal road to efficient sanitation.

CHAPTER XIV

DISPOSAL OF WASTE MATTERS IN THE FIELD

THE disposal of waste matters in the field is one of the most important and pressing problems in military sanitation. This is more particularly the case with civilized armies, since the men are on the one hand less inured to living in a condition of filth, and on the other more accustomed to having their conservancy managed for them by some impersonal central authority. The responsibility of the individual soldier in barracks for the proper removal and disposal of his waste matters is of the slightest, whereas in the field, with troops on the move or encamped for short periods only, each man has to be made answerable for the due performance of this task.

The difficulty and urgency of the problem are increased by the fact that removal is, under the conditions that necessarily obtain in the field, impossible. Disposal has consequently to be carried out *in situ*, and therefore at once. With regard to urine and fæces the point to be kept in mind is that they contain potentially the germs of infectious disease, but that those germs cannot gain access to the water and food supplies of the army unless provided with some form of transport. Immediate disposal can therefore be satisfactorily achieved if they are at once covered up so as to be inaccessible to wind and flies. This can be done in the simplest of all manners, which is at least as old as the Mosaic Law, by burial under a few inches of earth. For troops on the move there is no more efficacious method, and the immediate covering of excreta by earth should be taught to the soldier as an essential part of his field training. Any dereliction of duty in this should be promptly

punished, whether on the march or in camp. I am quite aware that the *Bacillus typhosus* can live in fæcally contaminated soil for a length of time as to whose exact duration no two bacteriologists seen to be able to agree. It is possible, therefore, that the buried excreta may by the next shower of rain be washed into some stream or underground water-channel. This danger cannot be ignored, though it is much less insistent than that of air-borne contamination of foodstuffs. It can also be guarded against to a very great degree by a rational selection of latrine sites, and in other ways. It remains obvious to me, therefore, that the immediate danger, which is also the greatest danger, can be most efficiently met by immediate covering over, or protection in other ways from access of flies.

The danger to be anticipated from any delay in disposing of other waste matters, food débris, etc., is the breeding of flies. The only satisfactory and safe method of disposal in this case is incineration, and, wherever possible, this should be carried out at once and *in situ*.

This last rule applies to all camps both standing and stationary. In the former it should be possible to make some more scientific scheme for the removal of excreta to a safe distance before burial. The conditions would, in fact, approximate to those obtaining in a cantonment where a hand-and-cart system of removal was in vogue.

Latrines.—There are two patterns of latrine generally used, which may be called the long trench and the short trench respectively. In the former, which is the old pattern in general use up to within the past few years, a trench was dug 4 feet deep, 3 feet broad at the top, 2 feet broad at the bottom, and 5 yards long for every 100 men. This is a bad pattern; it inevitably becomes fouled by fæcal matter and urine at the edges and the sides, and it is difficult to insure the complete covering up by earth of the fæcal matter in the trench. This pattern should, in fact, never be used. In the short trench system a number of trenches are dug, each 3 feet long by 2 feet deep and 1 foot broad. This is the ordinary rule, but I am indebted to Major Caldwell Smith, of the 2nd London Sanitary Company,

for the very useful suggestion that the trenches should be broader at the bottom than the top, say, 1 foot 3 inches at the bottom. As can be seen at once, this protects the sides of the trench from fouling. In loose, sandy soils this is not, however, always possible.

I am indebted to the same officer for the suggestion that the upper edge of the trench should be, as it were, rebated, leaving a ledge about 6 inches broad and 4 inches on each side of the trench; this not only prevents the soil at the edge from crumbling in, but gives a certain purchase for the feet when the soldier is in the squatting position (see Fig. 3). The essential point about these trenches is that they shall be used in this position, as by so doing all fouling of the back, front, or sides of the trench is prevented. The earth taken from the trench should be heaped up either in

FIG. 3.

front of or behind the trench, on no account at the sides, and will then be available for covering over the fæcal matter. In a stiff soil the earth must as far as possible be broken up, or if necessary some drier, more friable soil brought from some little distance. It is rare that even in the stiffest soils the upper 3 or 4 inches are not friable. Close to this heap of earth must be placed the sod removed when the pit was dug, which must be carefully replaced when the trench is filled. In the case where latrines have been dug on arable land this may be impossible. In such a case the earth must be well stamped down and levelled.

The distance between the trenches is of importance. This should be either 3 or 2½ feet. Personally, I am in favour of the former measurement, which is that most generally allowed. The only objection to this space is the

total amount of ground taken up by the latrines. The usual rule is to allow one trench for every twenty men—that is, of course, 5 per cent. of strength. For small numbers this allowance may be necessary, but for any number over 200 it is excessive. Some graduated scale should be fixed. Major Caldwell Smith has very sensibly suggested that the factory and workshop standard, as laid down by the Home Office, might be followed. This would give, if the force were less than 500, say, a cavalry regiment, or a half battalion or battery, four trenches for the first 100 men, and one for every additional 40 men, or odd number less than 40. This works out at 7 for 200, 9 for 300, 12 for 400, and 14 for 500. For a cavalry regiment with a strength of 526 men 15 might be allowed. Captain Tilbury Brown, who has paid considerable attention to this question, suggests 3 per cent. for 500 and over. For larger units—that is, for infantry battalions, the workshop and factory rules would allow one seat for 60 men or any odd number less than 60. That is, for a battalion, 17 trenches. Personally, I should regard this as rather low, and would prefer a 3 per cent. allowance between 500 and 750, and a 2½ per cent. allowance above the latter figure. The difficulty about a high allowance is the restricted area available in camp for digging trenches in. The rule is to place these at the rear of the camp, and they cannot of course extend beyond the lateral borders of the camp. In an infantry battalion this allows only 65 yards. If we calculate 4 feet for each trench, 1 for the trench itself and 3 for the interval, that amounts to 200 feet, almost 67 yards for the fifty trenches allowed on a 5 per cent. basis. With a 2½ feet interval between trenches one could, it is true, fit the whole fifty in, but naturally there is no object in digging more than are absolutely required. With smaller units, especially those which are mounted, the same difficulty does not arise, owing to the larger camp frontage available. Thus, for instance, in the case of a cavalry regiment 526 strong the frontage is 161 yards, and for a battery 200 strong, 75 yards, but here again labour is scarcer than in an infantry battalion, so on that account it is necessary to limit the number of trenches to the lowest limit possible. I have given the depth of trenches at 2 feet, and this is the usual

practice. With such a depth and good management one set of trenches can be used for as many as four days. If trenches are needed for one night only, 1 foot in depth is sufficient. Personally, I should prefer using each trench for one night only, but with good management they can, if necessary, be used for four days. The question is, to a great extent, one of space available.

The following instructions, modified from a paper by Captain Tilbury Brown, which appeared in the *Journal of the Royal Army Medical Corps* in July, 1909, are worth notice, in reference to the laying out of a latrine area. Taking the right-hand rear corner of the camp area as a

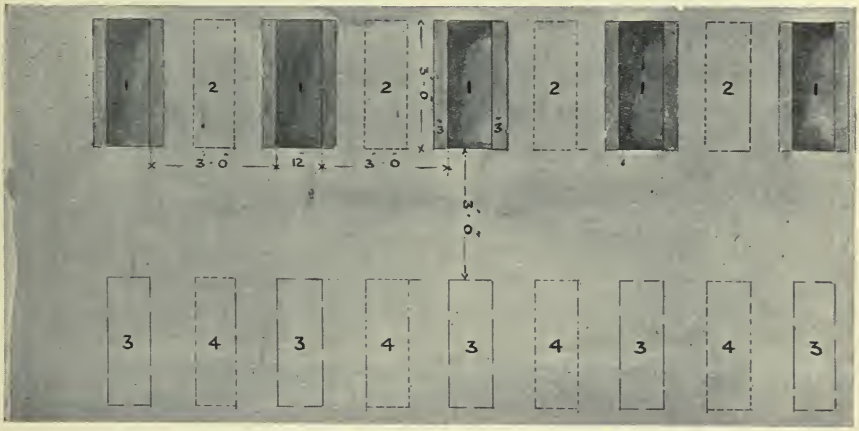


Fig. 4.

base, fix a tent-peg 3 feet in front of this, and draw a line from it parallel to the base line of the camp. Measure off first, 1½ feet along this second base line, and, after that, alternate spaces of 1 foot and 3 feet, till the full number of trenches, minus one, has been marked out. Beyond this mark measure off 1 foot for the last trench, and then 3½ feet beyond that again; place a peg to show the farthest lateral extension of the latrine area. This will give 3 feet between trenches, with a margin of 1½ feet to the right of the first trench, and of 3 feet 6 inches to the left of the left-hand trench. The trenches can then be dug and the screen placed round the latrine area, the two pegs already mentioned fixing the lateral limits of this screen. The screen

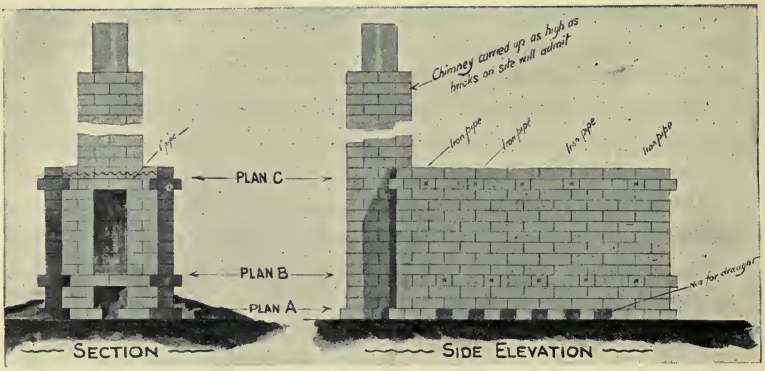
should be 3 feet clear of the back of the line of the trenches, and at least 6 feet clear in front of them, the total depth of the screened area being thus 10 feet. At the conclusion of the period through which it is intended that the latrine shall continue in use, whether that be one day or four, dig a second row of trenches in the intervals of the first row. The right-hand trench of this new row will be between the first and second trenches of the first row, and the left-hand trench 1 foot to the left of the left-hand trench of the first row. At the end of the second period these trenches must be closed up, and an entirely fresh row dug 1 foot in front (that is, nearer the camp) than the first two rows, corresponding in position exactly with the trenches first dug. It is not absolutely necessary to shift the screen, since there will still be 2 feet clear in front of the new rows of trenches, but it can be done if wished, and, for reasons given later, should generally be done. The length of time you can afford to use these various rows of trenches will obviously depend on the space available. Each pair of rows takes up 4 feet in depth, and, in addition, there are 3 feet behind the original row of trenches. Thus, in two days, if daily trenches are dug, or in eight, if each trench is used for four days, 7 feet in depth will have been used up ; and in four or sixteen, as the case may be, 11 feet. If the plan of daily trenches be adhered to, in a fortnight the area used up will be 55 feet in depth, say, 18½ yards. As a general rule, the trench system should not be used in camps which it is intended shall be occupied for even this period, and in no case for a longer one. In such cases some pail system of removal should be instituted, and proper wooden latrines erected. I will return to this later.

There are one or two minor points concerned with the working of trench latrines which I must touch upon. New rows of trenches should always be nearer to camp, and not farther away. Men will not in that case have to tread on dirty ground on their way back to their tents. Trowels or scoops should be provided in the same proportion as trenches are dug, if possible. If this proportion cannot be observed for any reason, then half that number must be furnished. It trowels are not supplied there will be more

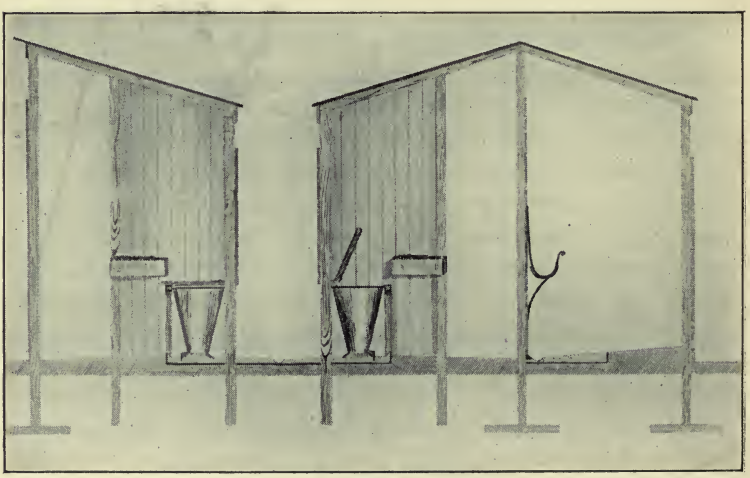
difficulty experienced in making the men observe the rule that all excreta should be covered up immediately after being passed. Paper should be provided, and kept in small bags or boxes, fastened to the screens. In addition to the large screen, running round the entire latrine, it is advisable, when possible, to supply smaller screens to run between the individual trenches. It is not necessary to have these at the back of the trench as well, if the large screen is always kept well up to the rear of the line of trenches. When troops are on the move, starting at an early hour every day, and some carelessness is apt to occur, I should like to see the surface of the filled-up trench-line scorched with fire, to destroy any possibly infectious matter that may have escaped burial. A little straw and some paraffin oil will effect this satisfactorily. One of the greatest dangers of camp life is due to neglect of troops leaving camp early in the morning, especially when the ground has to be occupied by other bodies of men immediately after. Of course, where there is heather or gorse close at hand, great care must be taken to see that the fire does not spread to a dangerous extent—further, that is, than is absolutely necessary. A thorough burning of the soil is not wanted, merely a short but severe scorching. Officers' latrines should be dug in the same way as men's latrines, and here again individual screening is very necessary. In no case should any form of seat or plank be allowed to be used by the men ; they are not only absolutely unnecessary, but inevitably lead to fouling. If the ground slopes, a catch-water drain should always be dug on the up-hill side of the latrine, and another between the latrine and the camp if the latter be down-hill from the former.

Whenever a camp is to be occupied as a permanency, then some more permanent form of latrine should certainly be erected. The diagram (Fig. 5) shows such a form. The buckets rest on a concrete platform and are well boxed in, in front, and provided with a hinged lid. This lid should be so constructed that it will close automatically as soon as the seat is vacated, with the object of keeping out flies. A double row of seats is shown, and the roofs are sloped so as to drain on to the concrete platform which is guttered to carry away any washings or leakage. It

can be swilled or scrubbed down if necessary ; in this case some arrangement should be made for disposing of the washings by means of under-drainage. A box is provided



Destructor : Permanent.



Latrine : Permanent.

FIG. 5.

for dry earth, and one scoop or trowel for each seat should also be issued. Each seat is in a separate stall, but it is not necessary to provide these with doors, and in no case

should full doors covering the entire doorway be provided ; a door covering the middle third is amply sufficient. In the diagram a urinal has been shown under the same roof as one of the rows of seats. This is, of course, not essential, but still very convenient. The disposal of urine in such cases is a matter of very great difficulty. A wheeled tank should, if possible, be provided into which the trough can drain ; the trough may be made of any impervious material, and will be much less likely to become offensive if frequently treated with some mineral oil. This prevents the deposit of urinary salts, and also discourages the presence of flies. It is necessary in all permanent latrines to take very strong measures against flies. In a permanently occupied camp it is extremely difficult to prevent a considerable collection of these insects, but it is possible to prevent their haunting the latrines and urinals, and this must always be done. The principle on which I act is to make the latrines and urinals reek with some smell which is obnoxious to flies. Spraying or swabbing with crude carbolic solution or kerosene oil, with frequent scrubbing of seats and tarring of the under-surface of these, are good measures. It is, however, not a matter of any importance how the flies are to be kept out of the latrines ; the method is nothing, the principle is the important point. I should, if inspecting a camp, judge of the efficiency of the sanitation very largely by the presence or absence of flies in the latrines and urinals.

Where latrines of this nature are used, some organized system of removal must be instituted. Preferably, this should be carried out in the latrine pails without any preliminary emptying of the contents of these into a cart. If a light rail or tramway can be constructed for the purpose, so much the better. If the pails are protected from flies while in the latrine, and then transported quickly and safely to a distance of, say, one and a half or two miles, the danger of disease from this cause will be largely reduced. Such a method of removal would, of course, entail considerable initial expenditure. In the majority of cases in a standing camp, even in time of war, the soldier is much more likely to die from disease than from gunshot. Good conservancy is, therefore, even as important, if not more

so, than fortification, and any money spent on it will be well expended.

In standing camps disposal should always be by incineration, either in the latrine itself, or preferably, if possible, at some distance from camp. This last method presupposes a well-managed and well-thought-out system of removal. As to the pattern of incinerator used, it is impossible to lay down any law. Some improvised form may be installed, or a proper destructor built. In the latter case it will be unnecessary to remove the excreta to so great a distance. While speaking of this subject, I should like to say one word about the immense value of paraffin or kerosene oil as a sanitary store. All incineration schemes will be greatly assisted by its use, and as a fly deterrent it has no superior. It possesses in addition the advantage that it can be procured almost everywhere, and especially easily in the tropics.

Excreta in camp can be disposed of by incineration, and this method is, in fact, much practised in America. The most commonly used one is the McCall incinerator. This consists of two combustion chambers placed at right angles to each other, with a common flue or chimney. Each chamber consists of two parts. The lower is of brickwork, and this is built up in a pit 24 inches deep, of which the bricks form the walls. Above the brickwork is a steel box containing two incinerator pans in which the fæcal matter is received. Above this again comes a removable wooden seat. When it is desired to incinerate the contents of the pans, the wooden seat is removed and the two incinerator pans closed by two hinged iron lids, which, when the latrine is in use, are raised up and rest against the sides of the wooden seat. The incinerator pans communicate with the common flue and chimney, and in this flue a grate is placed. In this last a coke fire is lighted, and after this has been thoroughly started a wood fire is lit in the brickwork chamber underneath the incinerator pans. The coke fire in the grate acts as a secondary combustion chamber for the destruction of unpleasant fumes. Urinals are constructed in connection with these incinerators, and after the combustion is complete, and the fæcal matter destroyed, the urine is run into the hot pans slowly, and thus evapor-

ated. Though primarily intended for use in standing camps, a portable form has been made in which the brickwork chamber is replaced by sheet steel firebox lined with asbestos. This weighs 1,800 pounds for four seats—that is, for 160 men at the outside, calculating for the proportion of one seat for 40 men. This adds a weight of 10 pounds per man to the transport. Other forms of incinerator are the Jones, which is practically an extemporized form of McCall, and the Conley. These, like the McCall, are worked on the intermittent plan—that is, the fire is only lighted at intervals. In the Lewis and Kitchen pattern a fire is constantly kept burning and the excreta are from time to time raked into the fire and burned there. An arrangement also exists for the destruction of urine. According to Colonel Havard, of the United States Medical Corps, unceasing attention is required to prevent the fire going out or else becoming so brisk as to render the seats uncomfortably hot. The intermittent pattern of incinerator has the disadvantage that the excreta are kept in the vicinity of camp for some hours, and may thereby attract flies. This can be obviated by the use of deodorants. Incinerators have not been received with much favour in this country, but in America they are thought highly of. The possibility of their use in large standing camps should be remembered, as it is easy to understand conditions under which other methods of disposal of excreta might be difficult or impossible.

In the *Journal of the Royal Army Medical Corps* for October, 1910, there is an interesting account of a pattern of incinerator used in the 101st Grenadiers, one of the old Bombay regiments of the Indian Army. This aims at providing a portable incinerator, and as it seems to me extremely practical I venture to describe it in some detail. Iron pans of $\frac{1}{8}$-inch sheet iron, and intended for the reception of excreta, are provided on a 5 per cent. basis. These are made of various sizes, so that they can be packed in nests of six, the dimensions of the outside member of a nest being 1 foot 2 inches long by 5 inches broad and 9 inches deep. Two nests are packed into a large iron box with a lid which serves afterwards as a general receptacle. Of these there are four for a battalion 832 strong, containing forty-eight pans.

In the inside member of a nest a tin of kerosene (paraffin) oil is packed. The actual destructor or incinerator consists of a truncated pyramid, of which the four sides are hinged to each other, in such a manner that the whole can be folded flat. The material used is $\frac{1}{8}$-inch sheet iron. The dimensions of the destructor when complete are 2 feet in height, 2 feet square at base, and $1\frac{1}{2}$ feet square at top. There are two rows of square apertures in each face of the pyramid, for ventilation, the total number being sixteen. This piece of apparatus is placed over a shallow hole in the ground in which a fire is lit. In practice the various pans are placed in holes dug in the ground made accurately to receive them, any interstices being luted with mud. Immediately after use the native sweeper passes one of the pans through a mixture of water and kerosene oil contained in the metal boxes already alluded to as carrying the nests, the fæces being retained in this receptacle. When it is decided to burn the excreta this receptacle is placed inside the incinerator and burnt. It is not quite clear to me how the details are managed, whether the water is poured into a hole in the ground or not, and there are other minor points on which I am still in doubt. Still, the principles on which the apparatus is worked seem sound, and I would suggest that one of the sanitary companies at its next camp might make experiments with some pattern of this nature. Indian regiments benefit much by possessing a regular establishment of sweepers who are by caste and training accustomed to dealing with excreta. The total weight is, it is true, considerable—about 453 pounds, or three mule loads for a battalion 832 strong, rather over $\frac{1}{2}$ pound per man. It is not stated in the paper, written by Colonel Betham, of the 101st Grenadiers, if the system works without nuisance, but he evidently has a great opinion, founded on experience, of the efficacy of its working.

Urinals.—An excellent pattern of urinal is that described by Captain Tilbury Brown in the *Journal of the Army Medical Corps* for June, 1909. This consists of a pit about 4 feet square, which is refilled loosely with the earth dug out, or with stones. Into this pit run two trenches each 12 feet long and 2 feet wide, with a gradient of 1 inch for each foot

of run. The depth at starting should be sufficient to give a distinct beginning to the trench. This is large enough for a battalion. The earth dug out of the trenches should be thrown to the outside and heaped there, the trenches being themselves lined with small stones. The pit should be guarded with a screen, hedge, or wall, so as to prevent men urinating direct into it. As soon as the trenches show signs of becoming offensive, they must be filled in and new ones dug. A catch-water drain should be dug on the uphill side of the urinal to prevent swamping in heavy rain. In stiff soil there is apt to be some difficulty, as the urine will simply collect on the surface of the filled-in pit. I am much indebted to Major Caldwell Smith for a very ingenious suggestion for use in this case. The pit and trenches are dug as before, and the former is filled at first, and to about one-third of its depth, with old tins and burnt rubbish from the camp destructor ; the neighbourhood of any works where clinkers were procurable would naturally be of great assistance. On the top of this lumps of dry earth are placed, and on the top of these again dry earth broken up fine. The urine runs along the trench, and is received at the end into a pipe made of empty cylindrical tins without tops or bottoms, which runs diagonally downwards to the bottom of the pit on the opposite side (see Fig. 6). The urine now has to filter upwards through the filling-in of the pit before it can appear at the top, and this affords an opportunity for evaporation and oxidation. I consider this model preferable to the original pattern, and should feel inclined to adopt it for any urinal intended to be used through any period longer than two or three days, whatever the soil conditions. The urine, being conducted to the bottom of the pit, is at once protected from flies. A simpler form can be used for a small body of men, or till the more elaborate structure can be made. This consists of a pit into which a steeply sloped gutter runs, the actual point of junction being the bottom of the pit. The pit is filled in as before, but on the side where the gutter enters a board is placed, at least as broad as the gutter, which closes all access of fluid to the pit except at the very bottom.

Disposal of urine at night is always a great difficulty. The tendency to be careless in this respect is universal, and

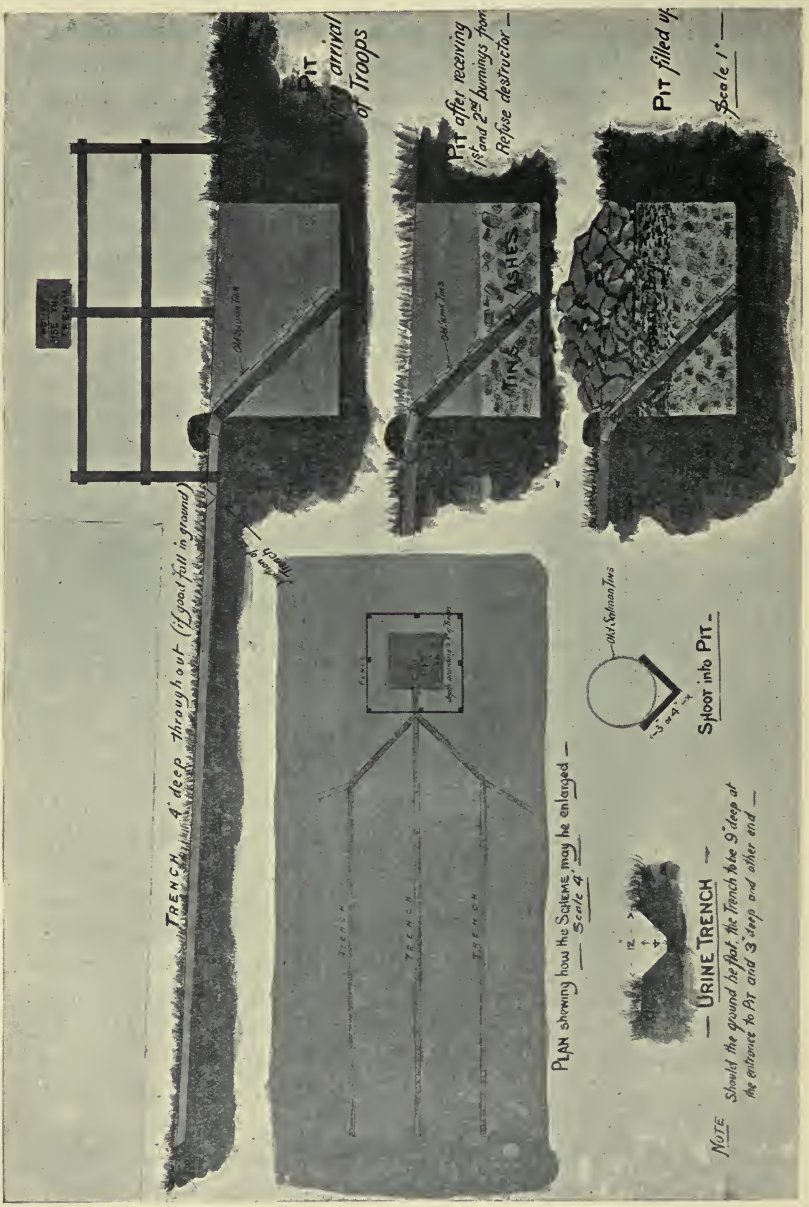

TRENCH 4' deep throughout (if good soil in ground)
Pit on arrival of Troops
Pit after receiving 1st and 2nd burnings from Refuse destructor
ASHES
Pit filled up
Scale 1"
PLAN showing how the Scheme may be enlarged —
Scale 4"
— URINE TRENCH —
Should the ground be flat, the Trench to be 9' deep at the entrance to Pit and 3' deep at other end —
Shoot into Pit —
NOTE

FIG. 6.

yet urine is no less important a source of disease than fæcal matter, more especially in the case of that most serious disease, enteric fever. The proportion of convalescents who act as urinary carriers of this disease is very considerable, and the numbers of bacilli that they discharge per diem simply colossal. In one case in which the numbers of bacilli were calculated over a considerable period by Captain Fawcus, of the Royal Army Medical Corps, the daily output amounted on one occasion to 500,000,000 in twenty-four hours. It is important, therefore, to provide special night urinals, since the day urinals will obviously be placed too far away for use in the dark. It is not very easy to do this satisfactorily. The usual method is to place tubs or buckets on mounds of earth of a suitable height, with a lamp hung close by. This lamp is essential in standing camps. The difficulty lies in the fact that if the tub is large there is always a certain amount of difficulty in removing it without spilling, whilst if it is too small there is a danger of overflow. A large number of small, easily portable buckets is more practical than a smaller number of comparatively large tubs. In carrying these it is worth while remembering that a few leaves of bracken or fern floated on the top of the urine will do a great deal towards preventing splashing. For troops on the move, broad, shallow pans should be dug at the ends of the rows of tents. In loose soil it will be sufficient if the turf is merely taken off or the surface turned over, but in heavier soil a cavity must be excavated.

Where night urine tubs are used, it is necessary to provide a pit into which they may be emptied. For this purpose a special pit may be dug, or the day urinal be utilized. I prefer the former plan, since it allows of the pits getting a rest, and the urine filtering or evaporating away.

The disposal of urine in standing camps of long occupation must always present great difficulties. Its bulk and weight (2 pints or 2½ pounds per man—that is, 250 gallons, about 40 cubic feet, or over 1 ton for a battalion) renders it a most difficult matter to handle. Personally, I think that urine pits as already described are probably the best method. The pit should always be so constructed that the urine shall be conducted to the bottom of the pit, as shown in Fig. 6, not allowed to flow over the surface.

Clearly, if this course is adopted, the urine is actually kept in the camp, and disposed of *in situ*—a method which would be impossible in a standing camp in the case of solid excreta. *Prima facie*, this seems to possess many objections, but I think these are more apparent than real. It is necessary to remember that urine contains only 5 per cent. of solid matter in solution. The enormous bulk of it, therefore, is water which is incapable of causing a nuisance. If it is allowed to penetrate at once to the bottom of a filled-in soakage pit, the danger of infection being carried by flies is reduced to a minimum. There remains only the nuisance attributable to the ammonia emanating from the carbonate of ammonia resulting from the decomposition of urea. A layer of lightly rammed earth placed on the top of the pit, or wood ashes, about 9 inches deep, would satisfactorily mitigate this nuisance. I am perfectly convinced that such a measure would be infinitely preferable to attempting to convey the total bulk of liquid away in tubs or buckets, with the liberal splashing of potentially infective urine that would inevitably occur. The daily burning of litter on the surface of the filled-in pit would equally obviate any possible nuisance. In this case kerosene oil should, if available, be freely used.

The sites of all latrines and urinals must be marked out when a camp is evacuated, and this can best be done, in my opinion, by heaping litter over them and igniting it. This will effectually destroy any infectious particles which may have escaped covering over in the hurry of quitting camp. Additional marks may, of course, be placed, if considered necessary, but the first-named procedure I consider essential. It is the last duty of a medical officer of any unit, when leaving a camp-ground, to see that, as far as possible, the site is left in as good a sanitary condition as it originally was prior to occupation.

I look on an efficient system of latrine and urinal construction and management as being the keystone of practical sanitation in the field. The medical officer of the unit is responsible for the patterns used, and must see that the details of construction are carefully carried out. He is responsible for the management, too, in so far as it is his duty to see that latrine pits are carefully covered in, and

that both these and urinals are not allowed to be used for a longer period than is proper. But the real management of both these installations is the duty of the men and officers of the unit. The sanitation of any unit is what a mathematician would term a function of the discipline of the unit. The better the latter, the better the former. This personal responsibility for the details of conservancy must be impressed on every individual in the unit with the utmost power at the medical officer's command. Some of these details are in themselves necessarily unsavoury, and it is sometimes urged that this unavoidable quality renders their due fulfilment derogatory to the character of the soldier. In this connection I venture to repeat two historical illustrations which bear strongly on this particular point—namely, the relation between the true military spirit and the performance of duties which, however necessary they may be, cannot be looked on as other than menial.

My first illustration is a quotation from the Life of Sir John Moore, and runs as follows : " The streets leading to the citadel being dirty, a battalion was ordered to cleanse them. It was represented that the men might object to this, but the order was peremptory, and obedience was insisted on. When the men assembled, and were told what to do, they in anger threw down their shovels and dispersed, saying that they were enlisted as soldiers, not as scavengers. This was passed over, but the battalion afterwards became very troublesome." The second instance is an extract from certain Standing Orders just 100 years old, and this runs as follows : " In towns, necessaries must be dug in the yards of houses, or in the most convenient situations adjoining buildings occupied by troops. They must be covered over daily, and fresh ones made as often as expedient. Fatigue parties will be frequently employed in removing and covering over the filth, which, notwithstanding these regulations, may have so accumulated as to render parts of the town or ramparts offensive. And if the quarters of any particular corps are found to be dirty, some restraint or additional fatigue duties will be imposed on that regiment." The incident first related occurred in Corsica, when Sir John Moore served there during the Governorship of Sir Gilbert Elliott. The recalcitrant battalion was one of Corsican Infantry, which,

if remembered at all, will probably be remembered only by the disgraceful act of disobedience just related. The Standing Orders from which I quoted are those "given out and enforced by the late Major-General John Craufurd for the use of the Light Division." The Light Division in the Peninsular War was, beyond question, one of the very finest military organizations that have ever existed, and Major-General John Craufurd was a man who, when he gave orders, made no mistakes about their enforcement. There is little doubt that the above orders were literally carried out. What was not beneath the dignity of the Light Division to do is not beneath that of any man in any army, and the question as to whether it is better to be soldiers *and* scavengers with them, or soldiers and not scavengers as the Corsican Light Infantry were, is one the answer to which I feel certain few soldiers would hesitate in making.

In this connection, the following quotation from an order by the famous Russian General Skobeleff, is of interest. It is dated at Duz-Olum, in Trans-Caspia, November 16, 1880, and runs as follows (after four orders relating to sanitation, and referring to the management of latrines, etc.): "This does not, however, diminish the responsibility of commanding officers, and they must always remember that the good state of a camp is a tolerably just measure of the efficiency of the troops occupying it, of the attention to their duty shown by commanding officers, and even of the preparation of the troops for battle" (Grodekoff, trans. Grierson).

We now come to the consideration of those forms of waste matter which are not specifically dangerous, but, owing to their putrescible nature, have to be removed to prevent the occurrence of a nuisance. These are tent-sweepings, kitchen refuse, kitchen slops, and ablution water, and litter from the mounted and transport lines.

Taking tent sweepings and kitchen refuse first, there is only one satisfactory method of disposal, and that is by fire. With regard to the first, in a standing camp it is necessary to have some definite system for collection. Perhaps the best way is to have a bag or tin hung on a pole at the end of each line of tents. The orderly men of the tents then collect the sweepings, paper, odd fragments of food, etc., from their respective tents, and place them in the

nearest receptacle. At a definite time each day, or, if possible, twice a day, the bags are all taken to the common destructor, and there incinerated. As they are mostly of a dry nature, their fuel value is considerable, decidedly greater than that of the heavier kitchen rubbish ; and if possible they should be thrown into the destructor at the same time as this latter in order to facilitate its complete combustion. The kitchen rubbish must be collected in proper bins if these are available ; if not, empty boxes or tins covered in some way must be utilized. Periodically these must be taken to the destructor and burnt there, and the golden rule is : " Sufficient unto the day is the rubbish thereof." No rubbish should remain overnight in or near a kitchen.

The next step is the construction of an incinerator. The best form consists of a small enclosure surrounded by a circular or rectangular wall composed of sods, bricks, or " bully-beef tins, " either empty or filled with earth. Good sods are perhaps the most durable, but tins filled with earth, especially if this be clayey in nature, are a very excellent substitute. In addition, they are always procurable. When sods are used, they should be 9 inches broad and about 2 inches thick. The walls may be supported by stakes borrowed from the fuel issue or specially cut, or else by heaping up earth round them. The walls should be 3½ to 4 feet high, since this is a convenient height to lift refuse baskets and boxes for emptying. A reasonable size is about 2 feet 6 inches square. Air should be admitted by holes left at the bottom of the walls, and these may be converted into long air-ducts by means of corned-beef tins placed end to end, projecting, as will be seen from the diagrams, to a varying extent into the area of the destructor. It may, especially if the weather be damp, be necessary to use a certain amount of fuel with some paraffin oil to start the fire, but subsequently, with good management, it should be possible to keep the destructor going by means of the rubbish and sweepings alone. Periodical stoking is of importance, as otherwise the fire may die out, or be choked by sudden overloading.

With such a destructor, unless rubbish is allowed to accumulate to an unmanageable extent, there should be no diffi-

culty in entirely disposing of all the rubbish for a battalion, provided care in management is exercised.

For purely temporary use, such as in a camp occupied for only one night, a semicircular wall may be made of earth and stones with the opening towards the wind ; the rubbish is then heaped together inside this enclosure and burnt.

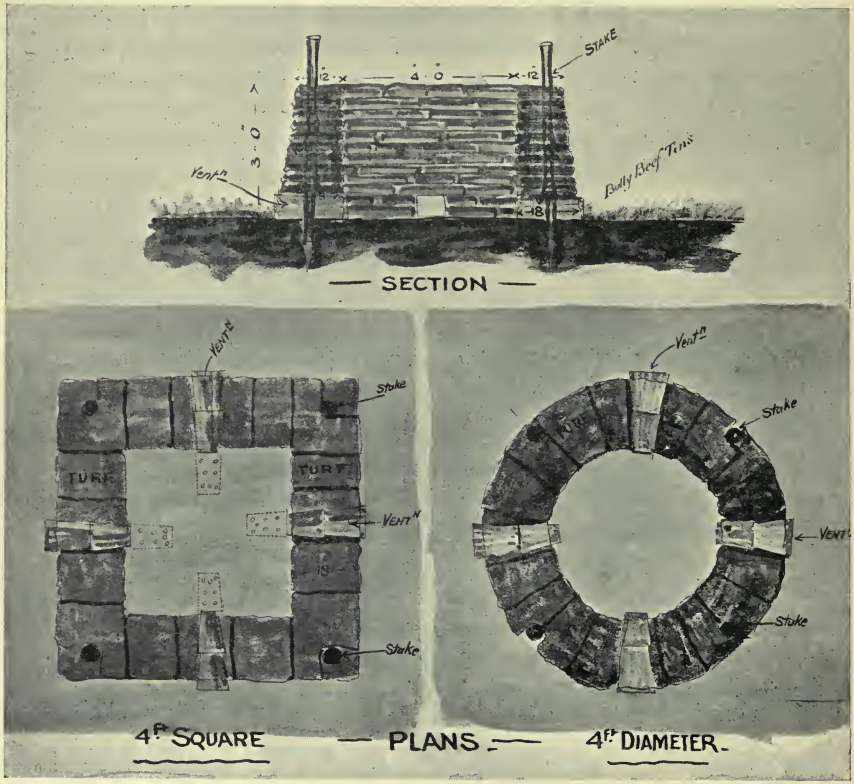


Fig. 7.

The function of the wall is simply to allow of the rubbish being heaped up against it. Burial, of course, may also be resorted to in such temporary camps, and the choice of method, whether burial or burning, may be allowed to depend on the nature of the soil and the labour entailed in digging, the time available, etc.

Colonel Firth suggests a simple pattern of incinerator, in

which two trenches are dug at right angles to each other about 9 inches deep and 5 feet long. A chimney is built over the intersection, and a few pieces of railway iron or other material used to form a grate or grid at the bottom of the chimney.

The " Arnold " or " rock-pile " crematory has been much used in the United States. It is made in the following manner : A circular pit is dug measuring about 15 feet in diameter and 3 feet in depth. The whole of the floor of this pit is paved with loose large stones to a depth of 14 to 16 inches, and on this pavement is built a circular wall, which acts as a lining to the earth wall of the pit, and projects 1 foot above the level of the surface. Earth is heaped up against this wall on the outside to form a sort of ramp, which provides a sloping access and also prevents surface-water entering the pit. In the centre of the pit a pyramid of stones about 5 feet high is constructed, which thus projects 1 foot above the level of the wall, and 2 feet above the general surface. This last structure is essential to produce a draught. If the contour of the ground permit, it is suggested as an improvement to construct the incinerator close to the edge of a sloping bank, so that an opening about 2 feet wide may be dug in the circular wall for the removal of ashes and the provision of increased draught. The incinerator is started by lighting a wood fire in it, which heats the stones forming the floor and wall to such an extent that any rubbish subsequently deposited is rapidly dried and burnt ; fluid slops can also be disposed of in this crematory.

The choice of structure to be adopted must be largely a question of local circumstances. If a camp were amongst sand-dunes near a shingle beach where good sods were not easily procurable, then the Arnold incinerator might with advantage be adopted. Where good sods are available, I feel inclined to plump for the square sod-built incinerator, as already described, and as made by the 2nd London Sanitary Company. The structure is, however, almost the least important part of the question. The essential conditions for success are system and supervision. Without these, no improvised incinerator can be expected to succeed. Every incinerator should be protected by a catch-water drain in case of heavy rainfall.

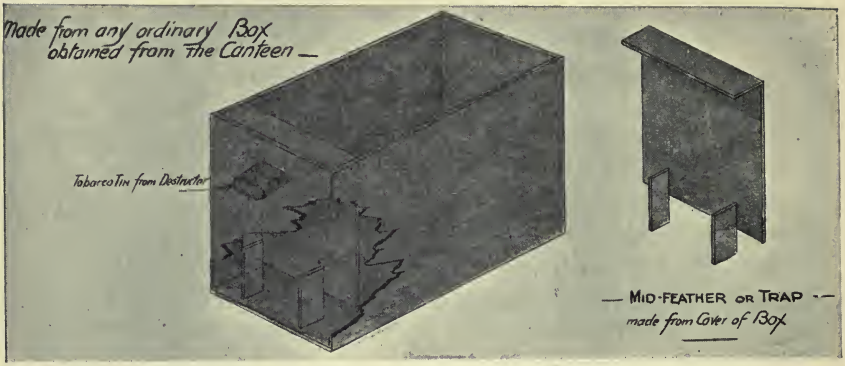
In situations where a more permanent installation is possible a destructor may be built on the lines shown in Fig. 5. This consists, as will be seen, of an oblong furnace with a chimney at one end, the whole being built of brick. The roof of the furnace is made of corrugated iron covered over with excavated material. The hearth is constructed of fire-bars made from corrugated iron cut into convenient strips. If possible, two iron rods should run longitudinally along the furnace to support these bars, and in that case the strips should be cut across the corrugations. This will facilitate removal of ashes. In the absence of this support, it will be advisable to cut the strips parallel to the corrugations. The actual dimensions of the furnace must depend on the size of the sheets available locally, and the thickness of the walls on the supply of bricks. In the diagram the walls are only one brick thick, and in such a case it is advisable to heap earth against the walls for the purpose of support. A piece of corrugated iron may be used as a half-door to improve draught after the furnace has been filled and lighted.

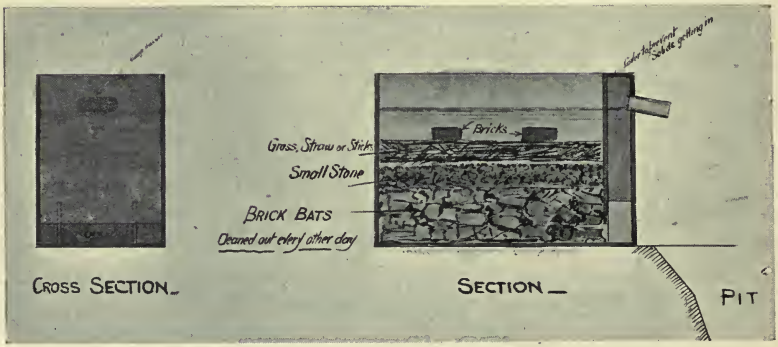
The next point to be considered is the disposal of kitchen slops. These also must be disposed of on the spot, and the difficulty consists not so much in their bulk as in the grease present. The problem to be solved is the removal of this grease, after which, in ordinary soils, the cleared water can be disposed of by soaking pits or trenches. The usual type consists of a rough strainer which removes the larger pieces of floating refuse—*e.g.*, potato-peelings, etc.—that may still remain in the slops, from which these pass into the grease-trap. This trap consists usually of a hollow in the ground, or of a tin in which heather, straw, grass, or leaves, are placed. The grease congeals on these, and the purified water then runs into shallow pans or pits, and is absorbed. The greasy heather, or whatever material may have been used in the grease-trap, is then burnt, together with the potato-peelings, etc., which may have remained in the first strainer. This method has the defect of being somewhat complicated, there being two receptacles to clear out. The 2nd London Sanitary Company have improved on this by constructing their strainer and grease-trap in one. A suitable box is taken and filled at the bottom with stones, above which is placed the

grease-retaining material. An overflow should be made near the top of the box, and an outlet also provided at the bottom (Fig. 8). In the absence of a box, a small sod enclosure could be made similar to that described for the destructor, and it might be possible in this case to use it as such, merely at the end of the day burning the grease-impregnated heather or straw *in situ*. In the absence of stones the lower half of the enclosure or box may be filled with empty tins. The drain from the grease-trap to the soaking pit or area may be lined with small stones, or even floored with empty tins flattened out. What should be aimed at is either to let the water soak into the ground in the drain-bottom at once or pass without delay to the pit. There must be no ponding of it in the drain. As regards the soakage area or pit, I am indebted to Lieutenant A. J. Martin, of the 2nd London Sanitary Company, for the suggestion that the important point in the construction of this is area, not depth, the upper layers of the soil being always more friable and more readily permeable than the lower. The pit should not be circular, as this entails more digging for the provision of surface than any other shape. A series of trenches, into which, if necessary, the water could be diverted on different days, or a broad, shallow pan, are preferable. In very impervious soil it is as well partly to refill the pit which has been dug with old tins, etc., on the top of which a layer of the excavated clay broken as fine as possible should be placed. The sullage-water is thus protected from flies, etc., till it has time to soak away. One or more of these can be made, and their use alternated.

In connection with this subject the question of washing dishes, etc., must be considered. If the men feed in their separate tents, then all this must be done in the vicinity of the kitchen, where only hot water can be procured. The dirty water should be freed from grease, and disposed of as already described. Even where dining-tents are provided, the washing-up should generally be carried out in the vicinity of the kitchen. In standing camps, if possible, trestle-tables, with or without a central trough, as described later, should be provided.

An important form of waste water is ablution-water. If care be not taken, the ground in the neighbourhood of the


Made from any ordinary Box obtained from the Canteen —
Tobacco Tin from Destructor
— MID-FEATHER OR TRAP —
made from Cover of Box


Gross, Straw or Sticks
Small Stone
BRICK BATS
Cleaned out every other day
Bricks
CROSS SECTION —
SECTION —
PIT

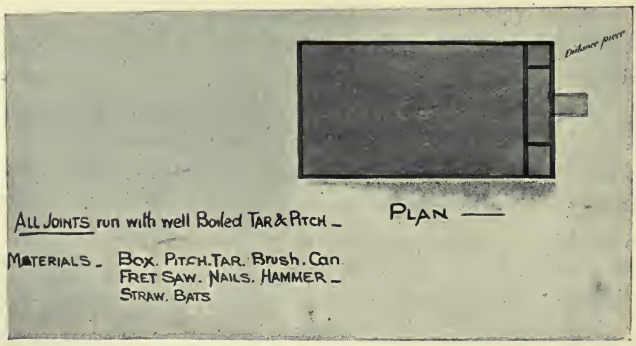

All Joints run with well Boiled TAR & PITCH —
PLAN —
MATERIALS — Box. Pitch. Tar. Brush. Can.
Fret Saw. Nails. Hammer —
Straw. Bats

FIG. 8.

washing-places may rapidly be converted into a disgusting swamp, especially in a clay soil, and the resulting mud carried into the tents. The first point to be considered is the ablution-bench. These should always be constructed in standing camps, and a good pattern is as follows : A trestle-table is constructed having a V-shaped gutter running down the centre. Above this gutter, and projecting slightly into it, should be a plank running longitudinally along the table. The men wash in their basins on the bench, and then tip the water into the longitudinal gutter. This last structure prevents any splashing of the men standing on one side of the bench when basins are emptied on the other. The place where the men stand should be paved either with concrete or loose stones well stamped in. The gutter discharges over a trench in the ground, which runs to any convenient distance, and then spreads out into a series of short trenches arranged herring-bone fashion, or otherwise, as may be most convenient. The extent of soakage area required will, of course, depend very much on the nature of the soil—whether, that is, it is readily pervious or not. Here, again, the water must either soak in rapidly or run away rapidly. The former may occur in loose soil, but if the soil does not permit of this, then the gutters should be made as impervious as possible, and with a good gradient, to prevent formation of puddles. If a bench cannot be constructed, on account of want of material or time, or from any other cause, then a canvas trough may be used, or, finally, the men may wash at the actual source from which the water is drawn. I need hardly mention that this must be below the places marked out for provision of drinking-water, and for watering animals, if the source be a stream, and as far distant as possible from these if the source be a pond or lake.

In hot weather it is well, if possible, to provide some sort of shower-bath where actual bathing is impossible. This, of course, demands a piped supply of water, and is only feasible in a camp occupied for a considerable time. The Americans provide five such per company in addition to 10 feet of washing-trough, made of cast-iron, per company. Every effort should be made to encourage daily washing of the feet, especially, of course, in the case of infantry soldiers.

To enable a man to do this in any comfort, and without wetting his clothes, it is absolutely necessary to provide him with some sort of seat or bench to sit on while so occupied. It is impossible to lay down any scale for these ; the more the better. With less than 15, or say even 20, per cent., there must inevitably be delay in the process. In all standing camps, special structures should be erected to shelter the men whilst washing, or else marquees or other tents pitched. In cold weather some arrangement for hot baths should be made. In or close to large towns it should be possible to make some arrangements with the local authorities for the use of the public baths for this purpose. Near the sea, or where a large lake or river is available, bathing parades should be held in warm weather, not only for cleanliness, but also for instruction in swimming.

The disposal of the excrement of horses and other animals is always a troublesome question, on account of the bulk of material involved. It may, of course, be possible to dispose of this waste product to a contractor, who will be glad to take it for manure. If this be done, very stringent conditions as to regularity of removal should be laid down and enforced. Removal should take place at certain defined hours, and in case of delay beyond a fixed period of grace the dung and litter should be burnt. Pending removal, these matters must be kept at a spot some distance from the camp, and, if possible, not in the direction of the prevailing wind. As a rule, mounted corps are very apt to be careless in this matter. This is, perhaps, natural with the men from whom a great number of our yeomen are drawn—the farmer class—since they are in the habit of seeing such accumulations of manure close to their dwellings. At the same time, such accumulation must not be allowed in camp, as it inevitably leads to the breeding of flies.

Latrines, urinals, etc., are arranged in the rear of the camp in a space termed the "sanitary area." Behind everything come the latrines and urinals for day use. A separate urinal should be made for officers. Between the latrines for men and those for non-commissioned officers a separate urine-pit is shown, into which it is intended that the night urine tubs should be emptied, the empty tubs or pails being stacked round this during the day. The in-

cinerator is placed close to the latrines, but it is a question whether it should not be nearer to the kitchens to save carrying about of rubbish and irregular stoking.

Before leaving this subject of camp conservancy, I should like again to draw attention to that most useful adjunct—paraffin oil. This substance is practically universally procurable, it is cheap, and one of the best fly deterrents that I know. In addition, its inflammable nature makes it useful for assisting incineration in unfavourable weather. The only other disinfectant that I should recommend for camp use is chloride of lime, which may be usefully applied round the sites of night-urine tubs or pails. These are the most difficult things to deal with that we meet in camp conservancy. They are a standing danger, but it is difficult to see, human, and especially soldier, nature being what it is, how they are to be avoided.

CHAPTER XV

BARRACKS

Barracks are buildings intended for habitation by men leading a communal life under discipline. They differ from other buildings to which the same description might be applied, in that the discipline to which the soldier is submitted is not merely a means of restraint intended to restrict his personal liberty, but an important part of that education whose end is to teach him to work in unison with his fellows in the performance of their common duty. A certain limitation of liberty is naturally implied in this, but this restraint is in the nature of a side issue only. The real object of barracks is to enable the men to know each other as the result of living together, and thus to form from a number of isolated individuals that organic whole which we term a regiment, battalion, or battery.

The life of the barrack is, in fact, one of the great influences which distinguish the regular soldier from the irregular volunteer, who meets his comrades only on parade, whilst all the rest of his life is absorbed in pursuits, and moulded by influences, which are different for every member of the unit.

The collection of a large number of men under one roof or in a number of contiguous buildings has certain very marked influences on their physical life, and forms one of the most important, probably the most important, of all those "surroundings" to which the recruit has to accommodate himself; it constitutes, therefore, one of the most pressing problems of military sanitation. The consequence of such an aggregation may very easily be detrimental to health, and, in fact, many military sanitarians have stigmatized barracks in the words of Boisseau, "as a necessary

evil the bad effects of which we must endeavour to palliate, without hoping ever entirely to do away with them." Or, again, as Bard says: "The life of the soldier necessarily entails a certain morbidity and mortality which result even more from the crowding together, and the communal life, than from the fatigues and exigencies of military service."

That the housing of men in barracks has in the past had a bad effect on their health is beyond dispute. At the same time I am by no means inclined to accept the argument that such consequences are the inevitable result of such a mode of life. I can see no essential reason why the soldier in barracks should not lead, not only as healthy a life as, but one more much healthy than, that of his brother who remains in the ancestral cottage or tenement building. The problems to be faced are no doubt difficult, but they are by no means insuperable, and their satisfactory solution is to be found in a scientific mode of planning and building barracks.

In the days when barracks were first brought into use the chief idea in the minds of the architects who designed them was to isolate the soldier from the remainder of the population, partly, no doubt, to protect the civilian from the excesses of an undisciplined soldiery, but partly, also, to enable the ruler to overawe the populace by a display of concentrated force. The idea of personal restraint was therefore the leading motive, and this is exemplified in the castellated barrack square attributed to Vauban, but in reality the work of a less-known man, Belidor. In these we have a central square surrounded and completely enclosed by four buildings of two or more stories. The upper floors were reached by staircases placed at the corners of the square. The men were accommodated in small barrack-rooms holding about twelve men each; some of these rooms looked on to the courtyard and some to the outside. In some plans the rooms were arranged back to back with a central partition wall; in others this wall was replaced by a dark and badly lighted corridor; in others, again, the rooms all looked outwards and opened into a long corridor running along the quadrangle face of the building. This last pattern was the best, as a certain amount of direct through ventilation was provided. The

rooms were used for all purposes, no extra dining or cleaning rooms, or even kitchens, being allowed. The latrines and other necessary buildings occupied a certain portion of the quadrangle. These barracks were chiefly objectionable on account of the fact that the aspect of at least two out of the four blocks was bad ; the courtyard was never properly aired, and a considerable portion of it never saw the sun, more especially during the winter months of the year. The paucity of means of access necessitated an undue amount of going and coming along the corridors, and any infectious disease once introduced had thus excellent opportunities of spreading.

The fact that troops had often to be concentrated in positions where they might be conveniently situated to overawe the more turbulent classes of the populace led to the placing of barracks in the most insalubrious and already overcrowded quarters of large towns. This, again, aggravated the initial defects of the plan on which the barracks were built. All the bad effects which residence in such buildings undoubtedly produced in the health of the army were essentially due to the false theory which appears to have dominated the minds of the men who designed them—namely, that barracks were merely places where the soldier could conveniently be confined until he was needed on parade.

Rational barrack construction in these islands dates from the appointment by Lord Panmure, in the year 1857, of a "Commission for improving the Sanitary Condition of Barracks and Hospitals." The Report of this Commission, published in 1861, should be read by every sanitary officer. It gives an excellent description, with block plans, of the typical barracks of that period, enumerating their chief defects as follows : As regards general plan, want of simplicity in the general arrangements of blocks ; buildings so placed as to interfere with the ventilation of each other, buildings erected around closed courts, or with deep closed angles ; barrack buildings placed too close to the boundary walls, with latrines, urinals, dung heaps, ashpits, etc., placed in a narrow space between the barrack and the wall. In addition they noted the following defects in internal arrangement—viz., placing barrack-rooms back to back,

with windows on one side only and no through draught; constructing barrack-rooms over stables; providing means of access to barrack-rooms by long internal corridors, or by corridors covering one side of the rooms; omitting to provide proper staircases; taking space for stairs out of barrack-rooms; using basements for barrack-rooms. The chief defect, however, was the monstrous condition of overcrowding, which was the almost universal rule. Thus, out of a total force of 76,000 men (in round numbers) about 1,300 lived in rooms affording less than 250 cubic feet per man, more than one-half had less than 400 cubic feet, and only 5,000 had more than 550 cubic feet air space per man. Taking the whole force, the deficiency in accommodation was estimated at about 32 per cent. In some rooms it was necessary to remove all the tables and forms before the beds could be folded down, whilst in some there was "hardly 12 inches between the beds in any direction; and when folded down for the night the beds appear to cover the whole area of the floor." The most important of all the recommendations made by the Commission was that in future every man should be allowed 600 cubic feet in the barrack-room. In planning of barracks they suggested that the simplest arrangement was the best; squares should be avoided, but where necessary the angles should be left open. The simplest arrangement proposed was a single line of blocks running north and south, so that both sides should be exposed to the sun every day, but this might be broken up into two parallel lines separated by a considerable space to be used for a parade-ground, and on occasion even more lines might be made, as long as these were placed "a sufficient distance from each other to enable the whole outer wall surface to be freely exposed to the sun during the day." The keynote of their scheme was decentralization, the unit being the barrack-room with certain appended parts "so that a barrack of any size may be constructed by simply increasing the number of units." The unit of size they placed at twenty to thirty beds, the beds being arranged with their heads to the walls on opposite sides of the room, the height of the room to be between 11 and 12 feet, with a breadth of 19 to 20 feet. The entire unit was to consist of (1) the barrack-room;

(2) the sergeant's room ; (3) an ablution-room with fixed basins ; and (4) a night urinal. The latrines and day urinals to be placed at as great a distance as may be convenient from the men's rooms, and the kitchens under a separate roof from the barrack-rooms, but at a convenient distance to enable the men's dinners to be brought to them hot. Baths and ablution-rooms were to be built in any convenient portion of the barrack enclosure, each bath being in a separate compartment, formed by a high bulkhead or partition, with a door and lock.

The general principles laid down by the Commission have formed the guiding rules for the construction of barracks since that date, and though advances in the science of building have rendered the decentralization recommended by the Commission no longer necessary, still, the general rules propounded hold as good nowadays as when they were first promulgated.

General Arrangement of Barracks.—It is clear that if a barrack is to be anything beyond a mere method of confining the soldier under cover, certain needs must be satisfied in addition to the provision only of a shelter. This will necessitate the construction of certain rooms or buildings in excess of the mere living-room, such as dining-rooms, recreation rooms, etc. The arrangement of these will depend largely on the barrack policy pursued. For instance, if decentralization is the ruling principle, the latrines, cook-houses, dining-rooms, etc., will need to be distributed throughout the barrack enclosure, so as to be in convenient proximity to the men. On the other hand, if concentration is to be aimed at, these accessory buildings can be all brought together and placed even under the same roof as the barrack-rooms. Decentralization has many advantages both from the sanitary and the administrative points of view. The responsibility for cleanliness can be more directly brought home to certain individuals, and the sanitation of each company placed under the hands of the captain and other company officers. On the other hand, from the point of view of construction (and especially that most important part of construction—drainage), centralization has much to be said in its favour, whilst administratively the important question of feeding

the men is much more satisfactorily handled from a central kitchen and a central dining-room than from eight or four such institutions. From the point of view of the comfort of the men, too, in an uncertain climate, it is only fair that in bad weather the soldier should be able to pass from the dining-room to the library or writing-room without going outside, and that after dark, at the close of day, he should be able to get to his bedroom without having to splash across a muddy barrack square. Modern progress in house construction has simplified the question very greatly and a degree of concentration is possible which was out of the question, or at least difficult, some years ago.

The reaction from extreme centralization to extreme dispersion was perhaps best marked in France in the Tollet pavilion system, in which the troops were accommodated in a number of isolated buildings, each one story high, and covering, consequently, an enormous superficial area. The expense of these, as represented by the ground that had to be acquired, was enormous, and the difficulty of warming rooms whose walls were all outside walls, the surface in contact with the outer air being as nearly as possible equal to that in contact with the air of the apartment itself, rendered them unsuitable for use except in a mild and equable climate. In the "type 1889" a return was consequently made to a greater concentration. Lemoine gives the Vincennes cavalry barracks as a type of this pattern. In these we see three buildings, each of three stories, all with the same aspect. In two of these two squadrons each are accommodated, each of these units being separated from the other by a main party-wall, and having its own sleeping-rooms, staircase, night latrines, lavatories, and dining-room. The fifth squadron occupied the upper part of the third building, the lower part being given up to offices, workshops, etc. The block plan of the main barrack buildings is H-shaped, certain accessory structures being disposed between these and the outer barrack boundaries. The barrack-rooms were provided with through ventilation and lighting by means of four windows, two on each side of the room. The cubic space afforded was 612 cubic feet, and the height was 13·2 feet.

In 1907 a return was made to the more scattered arrangement previously in use.

In the British Army decentralization was not carried to such an extreme as in the French Service, except in the case of the old camps at Aldershot and elsewhere, and by the end of the nineteenth century the half-battalion system was the general rule.

The block plan of this pattern may be compared to two capital T's joined together by their stems. The cross of each T was comprised by the barrack-rooms and ablution-rooms of two companies; the junction of the two shafts by a half-battalion kitchen, whilst company dining-rooms were arranged in pairs on the shafts themselves. The barrack-room must obviously be the first consideration. Even if it is used only as a dormitory, which should be the universal rule, the man must perforce spend a greater part of the twenty-four hours in it than in any other one room. In the plan under discussion each room is designed to hold twelve men; the cubic space is therefore 7,200 cubic feet, on the basis of 600 cubic feet per man. By a late decision of the Army Medical Advisory Board, the height is not to exceed (for purposes of estimation of the cubic space available) more than 10 feet. This implies a floor area per man of 60 square feet, and the general arrangement of the total 720 square feet of floor space is much as follows: The dimensions of the room are roughly 20 to 23 feet in breadth, and from 36 to a little over 31 feet in length. If the barrack-room has to be used as a dining-room, the latter breadth is necessary; but in cases where a separate dining-room is provided, the narrower room has certain advantages. The beds, each 2 feet 3 inches in breadth, are arranged along each wall. This wall is broken by three windows, each $2\frac{1}{2}$ feet in breadth, subtracting thus $7\frac{1}{2}$ feet from the wall space available for beds. These are arranged in pairs between the windows, with one in each corner; thus every man has a clear space on one side of his bed of about 6 feet, and $1\frac{1}{2}$ feet on the other. In the narrower room a central passage of about 6 feet is left, this being increased to nearly 9 feet in the broader room. The choice between the narrower and the broader dimensions is almost immaterial from a sanitary point of view. The narrower room is

somewhat more difficult to heat, and the through ventilation is slightly less efficient ; there is, however, but little choice in this direction. The real deciding factor is the expense of the roof girders. In the broad room these are more expensive, being not only longer but also stouter ; they thus exercise greater pressure on the walls.

The rooms are heated by fireplaces placed back to back in adjoining rooms, the doors being at the opposite ends. Thus each pair of rooms opens on to a common landing or passage, at the outer end of which is the ablution-room. Separate rooms for non-commissioned officers, with company store-rooms attached, are provided in the proportion of two to every eight barrack-rooms. The cook-house, as already stated, occupies the point of junction of the two T's. It communicates directly with the two double-company dining-rooms, and attached to it also are bath-rooms and drying-rooms. The proportion of baths is four for the men, and one for the sergeants of each half battalion.

The regimental institutes, canteen, guard-room, etc., were all under separate roofs, so that the concentration had in this case only gone as far as sleeping and feeding accommodation.

The latrines and urinals were also separate, and no night urinals were provided, a noisome arrangement, called the " urine tub " being placed in the landing or passage between every two barrack-rooms.

Considerable as was the advance made in these plans in the direction of increased comfort for the soldier, a great deal is still left to be desired. The ground covered by the barracks is considerable. The different buildings, with the parade-ground for one infantry battalion, cover 22 acres, of which the parade-ground takes up only a little over 3 acres. The actual buildings, therefore, cover well over 18 acres. The men have to go considerable distances in the open, and in bad weather they are apt to get wet, and introduce dirt into the barrack-room on their return. The bathing accommodation is deficient ; an allowance of four baths for the men of half a battalion does not admit of every man bathing as often as he ought to do, and naturally those occasions when a man most wants a bath are not infrequently those when all the men, having been

similarly occupied, are smitten by the same need. Inevitably some men go without, and the large number actually using the baths absolutely prevents any proper cleansing of the bath after a man has used it before another does the same. Such a condition of affairs is unpleasant always, and may conceivably be very dangerous. Still, there is no doubt that these barracks were an improvement on anything seen previously, when the unit of the barrack was the company barrack-room, as laid down by the Commission before alluded to, and when neither separate dining-rooms, sculleries, nor baths, nor covered ways from the barrack-room to other buildings were provided.

Latest Barrack Plans.—In the latest plans a return has been made to the principle of concentration, the building being so constructed that all the indoor life of the soldier can be passed under the same roof, and, at the same time, the entire battalion or regiment accommodated in the one building. The only completed barracks of this class are those erected for occupation by the Guards at Windsor. Others are, however, in process of construction at Redford near Edinburgh, for both cavalry and infantry.

Windsor Barracks.—These are intended to accommodate five companies of infantry at night, the remaining three being housed in existing buildings of comparatively recent date. The dining- and other day-rooms are sufficient for the entire battalion. The buildings consist of two parallel blocks, one three the other two stories high, separated by an open space of 75 feet. This open space is covered by a flat roof with large ventilating lantern lights. The ground floors of each of the two blocks are intended for use by day, the sleeping accommodation being provided in the upper stories. A complete innovation has been made by the introduction of a cubicle system. The cubicles open on either side of a long corridor, and are separated by partition walls 7 feet 5 inches high, leaving a space of 2 feet 7 inches clear up to the ceiling. The partitions do not come right down to the floor, a gap of 6 inches being left to permit of thorough cleaning. Each cubicle is 7 feet 6 inches by 6 feet. The bed is placed along one side, and the door is so hung that it can be thrown absolutely open to permit of easy inspection by the company officer. Each

cubicle has its own window, 2 feet 6 inches broad, the upper half of which is a fanlight, falling inwards, and controlled by a screw rod operated from the non-commissioned officers' room. A locker is placed in each cubicle, and a steel wardrobe, hanging hooks, and arm-rack are also provided. Heat is supplied from steam radiators in the passages, and lighting is carried out by electricity.

The greater part of the central area is taken up by two half-battalion dining-rooms, in direct communication with the kitchen and canteen, which are placed in the ground floor of the two-storied block. In one of these rooms a stage has been erected, and private lockers are placed at the ends of the mess-rooms in which the soldier can keep any personal purchases of food. The dimensions of the dining-rooms are 84 feet in length by 64 feet in breadth. The lavatories and latrines are situated towards either end of the central space. The latrines and urinals are not materially different from the same installations at any good railway-station. The lavatories contain basins, slipper-baths, foot- and shower-baths. The latrine accommodation provided comprises 44 seats, and the 32 urinal stalls.* There are 14 slipper-baths, 10 shower, and 26 foot-baths. For purposes of recreation there is a smoking- and games-room (109 by 20 feet), a reading-room, writing-room, and billiard-room. The various shops, stores, and offices find a place in the ground floor of the southern block.

The new barracks at Edinburgh, for cavalry and infantry, are on a somewhat different plan to those at Windsor, though the ruling idea is the same.

The cavalry barracks consist of a front block and two wings; these latter run back from the front block, the starting-point being about 30 yards from the extremity of each end of the front. The total length of the front is 420 feet, and that of each wing 350 feet; the enclosed area is thus decidedly broader than that at Windsor, being 14,700 feet. As before, the ground floor of the different blocks contains the various day-rooms and offices, whilst the central area is mainly taken up with the dining-room, which in this case is regimental. It communicates with the

* In addition, there are 30 seats and 13 stalls on the corridor floors, for night use only.

kitchen by means of a service corridor and service-room, and also with the canteen. At one side is a stage with dressing-rooms, etc.

The latrine accommodation is arranged in two blocks each containing eighteen pedestal closets with twelve urinal stalls, between which come the combined shower- and foot-baths, twenty-four in number. Between these and the dining-hall come six slipper-baths and eighty-four hand-basins. All this lavatory accommodation is at the southern end of the central area, the latrines and urinals being as far as possible from the dining-hall. As before, the ground floors of the barrack blocks are taken up with the different day-rooms, recreation-rooms, and regimental offices. The cubicles occupy the two upper stories, there being 96 in each of the three blocks on each floor, or 576 in all, besides rooms for non-commissioned officers. Access is obtained by three staircases in each wing, and four in the front block. The cubicles are separated into blocks of twenty-four by cross doors in the central corridor, and small lavatory annexes are supplied in the proportion of two for each corridor. These contain eight washhand basins, two urinals, and two water-closets for night use.

The infantry barracks, which have been commenced, are arranged on a block plan resembling a capital **E**. The length of the front main block is 360 feet, that of the two outer wings (the top and bottom cross-strokes of the letter) is 230 feet, whilst the central block is 110 feet long. The central area is thus broken up by the projection into it of the short central block. The two isolated portions thus formed immediately in rear of the main block are left open, and the remainder roofed in, and utilized for dining-room, kitchen, and lavatory accommodation. It may be objected that the uncovered part of the area would suffer from the same objections as the old barrack square, but as the opening of the **E** faces south this is, in fact, not the case. The small amount shaded by the low roof of the dining-hall is not sufficient to produce a bad effect. The other internal arrangements generally are much the same as those of the cavalry barracks just described.

That such barracks are an immense advance on anything previously constructed in this country, or any other, for the

matter of that, there can be no doubt. It is worth noting that discipline, when considered as a part of the communal life intended to educate the soldier and mould the organic life of the unit, has resulted in a barrack plan not unlike the solid square of Belidor. Break down the end walls of a typical barrack of those times and cover in the central area and you would arrive at an almost absolute imitation of the Windsor Barracks. In the later barracks now under process of construction in Scotland the resemblance of the new to the old is even more striking. From a sanitary point of view the greatest advance is undoubtedly in the dining and lavatory accommodation. The former is quite on a level with that of a good public restaurant, and the close connection between the kitchens and the dining-rooms must make for better serving and better feeding generally. Naturally, any battalion is compelled in such barracks to adopt at least a half-battalion, if not a battalion, system of messing. This particular emphasizes the connection between barrack discipline and barrack construction. The two cannot be considered apart, even when the element of personal restraint is kept as much in the background as possible.

The provision of shower-baths is a great advance. It implies the possibility of insisting on frequent washing without undue waste of water or time, and it robs the bath of all the dangers which a slipper-bath, used in a short space of time by a large number of men, indubitably possesses. It will undoubtedly be necessary, in my opinion, in the case of a battalion occupying such barracks for the first time, to post a sanitary orderly to see that the water-closets are properly used, to perform, in fact, the duties which are carried out by the attendant that may be found in the lavatory of any of the larger metropolitan termini. It will be necessary for the medical officer in charge of effective troops in such barracks to keep a very close eye on these installations with newly-arrived battalions. The old proverb *Corruptio optimi pessima* is peculiarly attributable to up-to-date sanitary arrangements.

The Cubicle System.—The opinions as to the advisability or otherwise of this system are various. The greatest advantage is certainly on the moral side. The possession of even a small private apartment confers on the possessor

a sense of ownership which has a distinctively moral effect. I well remember the famous Edward Thring, once Headmaster of Uppingham, insisting on the importance of every boy in a public-school having his own study, very largely on this account. It is sometimes objected that the new system will have a socially disintegrating effect, but this is, I think, an exaggerated fear. It will be quite easy to prevent men going up to their cubicles without good reason in the daytime, or before a certain hour in the evening, or at least exercising reasonable restrictions in this direction. The lavish provision of recreation-rooms on the ground floor may be confidently expected to encourage the men to spend their leisure indoor hours in the company of their comrades.

From the sanitary point of view the most obvious objection is in the direction of cleanliness. A room is difficult to clean in proportion to the number of corners. A barrack-room for twelve men has four corners, but twelve cubicles have at least twenty-four. The fact that the partitions do not descend actually to the floor has no doubt an important bearing on this objection, but here, again, new battalions will need to be specially educated in the art of each man looking after his own apartment, instead of throwing the responsibility on the orderly man for the day. As regards infectious diseases, the ease with which isolation can be effected is no doubt a great advantage. Ventilation is assured by the falling fanlight in each cubicle, which, as already noted, is not under the control of the individual soldier.

It might be expected that these new barracks, with the increased luxury which they provide, would be more expensive than those built on earlier plans. As a matter of fact, concentration has effected a saving on account of the lessened area required. The barracks at Windsor cover a total area of a little over 5,000 square yards, those for infantry at Redford, where more space is available, 9,200, and those for the cavalry regiment at the same place, 15,200 square yards. These figures are exclusive of married quarters and stables.

Barracks in India.—In India, speaking of the stations in the plains, dissemination is inevitable. The fact that ground is comparatively cheap permits of this being effected

without extravagance. In the period immediately following on the Mutiny of 1857 a considerable number of two-storied barracks were built, but they are not particularly satisfactory, and the usual rule is small half-company bungalows with single verandas. Until lately, in the standard plans each half-company bungalow consisted of two dormitories, each 20 feet high, in which 1,800 cubic feet was allowed per man. Between these dormitories a dining-room, on the scale of 30 square feet per man, was placed. A sergeant's room was provided at either end of the block, and a store-room in the veranda. The lavatories, cook-houses, latrines, and urinals are all in detached buildings. Until lately there was no attempt to combine cook-houses and dining-rooms under one roof, but this is now done, a very distinct advance on previous arrangements. In the older barrack plans each company had its own cook-house, and the large number of these establishments impeded considerably the removal and collection of rubbish. But the most striking sanitary defect was the enormous multiplication of latrines. In one Lines I counted as many as seventeen different latrines for one infantry battalion. Under circumstances like these it was impossible for the establishment of native sweepers to cope with its task, which was, in consequence, neglected, with the inevitable result. Not only were there too many latrines; those that existed were often badly placed. With a view to maintaining control, the company cook-house, wash-house, and latrine were frequently placed too close together. I have elsewhere referred to a notice-board indicating that all these three were housed under one roof; but though this must, it is to be hoped, be a solitary instance, I have on one occasion seen the cook-house and the latrine so close that to effect a passage between them was difficult.

In my opinion the cardinal principle in laying out barracks in India, or in any other hot climate, where a water-carriage system of removal is impossible, is to keep the number of latrines and cook-houses as low as possible, and to separate them by as large an interval as can be managed.

The following is the type plan which I should suggest for an infantry battalion: The men should be housed in half-company bungalows, of the present dimensions, arranged in

two rows 100 yards apart, the bungalows of each line being in echelon, and not at right angles to the general direction of the line. The distance between the different bungalows in the same line should be equal to one and a half times, or twice, the height of a bungalow, and the angle of the echelon should be about 30 degrees. In the central space should be placed a battalion cook-house with dining-room attached, or else two such buildings, one for each half-battalion. In close connection with the cook-house should be the bathing accommodation, consisting only of shower and foot baths. Slipper-baths are unnecessary for cleanliness, and the disposal of the large amount of water that they use is a matter of great difficulty.

I should prefer to have a single installation of this nature, on account of the great advantages possessed by a battalion system of messing, but a single battalion wash-house might occasion some difficulty. It might on this account be necessary to have two half-battalion buildings, each comprising, as above suggested, cook-house, dining-room, and wash-house. The day latrines and urinals should be placed at least 50 yards to the outer flank of each line of bungalows, so that there should be a good 100 yards' distance between them and the dining-rooms. The latrine and urinal should be combined under the same roof, with a view to disposing of all excreta in an incinerator, without undue carrying to and fro. It would probably be necessary to have four such buildings, each for a double company, as otherwise the men from the bungalows at the extremities of the lines would have too far to go in the middle of the day in the hot weather. For night use a small combined latrine and urinal should be placed fairly close to the bungalows, one for each company, between the two bungalows occupied by that unit. These should be kept locked between "reveillé" and "last post" in the hot weather, and between "reveillé" and "retreat" in the cold season. The most careful attention should be paid to these buildings to prevent any fly-borne infection passing to the bungalows. The key should be in charge of a non-commissioned officer, who should see that all excreta are removed from these to the larger latrines at "reveillé."

The married quarters should be placed at one end of the

battalion lines, the regimental institutes and offices at the other. The latrines for the married quarters should be kept as low in number as possible, and each quarter provided with one or two bath-rooms, in the ordinary Indian fashion, for night use.

As far as possible the lines of bungalows occupied by the men should run in such a direction that the prevailing wind should get free access to every building in the two lines. The married quarters should be to windward—that is, in Upper India, to the north-west of the barracks, the offices and institutes to leeward.

Such a type plan naturally could not be applied to every station rigidly; modifications must be made to suit local conditions, but the general principle, which I have already stated—namely, to limit the number of latrines and cook-houses as much as possible, and to keep them as far apart as can be managed, the former, if possible, outside the lines, and the latter inside—ought to be universally observed.

The individual bungalows should be of the usual type, and the central day-room should be preserved for use as a sitting-room in the middle of the day in the hot weather. This *might*—though I do not feel sanguine about it—lure the private soldier away from his bed-cot for a few hours at least of the "long, long Indian day."

Ventilation should be by clerestory windows and a ridge roof. The former should be built on a cross-frame, so that the opening could be closed with glass or wire gauze as required. These windows should be operated by rods or else by stout wires, not by ordinary string, as is, or used to be, the case. The ridge aperture should also be rendered fly, and if possible mosquito, proof, but in this case the gauze should be so placed as to be visible from the inside of the bungalow, and be easily accessible for swabbing. For hot-weather ventilation electric fans or some mechanically worked form of punkah should be provided, and the punkah coolie done away with. I feel certain that this wretched serf is responsible for a great deal of disease. Heating, if not on any central system, which is impracticable, in my opinion, should be from two fireplaces in each dormitory, not from one only. With the large cubic space allowed, one fireplace cannot supply sufficient heat for the

whole room except at the risk of scorching the men closest to it. The difficulty is the greater, since it is impossible to reduce the cubic space in stations where heating is most required in the cold weather, on account of the fact that these are, as a rule, also the stations where the heat is the most intense in the hot weather.

I have already, in Chapter XII., given my views on the construction of latrines and urinals.

As regards bathing accommodation I have already said that this should be provided in connection with the kitchen. It might be advisable to build ordinary ablution-rooms in addition, where the men could wash in the ordinary sense, and these should be on the outer flanks. In that case foot-baths might be placed in these buildings. The bathing accommodation should be lavish, so that every man can have a shower-bath every day in the hot weather. This should not be impossible, since at this season battalions in the plains are at their lowest strength. It is impossible in the hot weather to keep the person from offence to one's neighbours with any less frequent ablution.

Inspection of Barracks.—Paragraph 134 of the Regulations for the Army Medical Service, lays down that "the medical officer (in charge of effective troops) will visit every portion of the barracks at least once a month." This duty is perhaps the most important that the medical officer has to perform, and it is at the same time one of the most difficult of all to carry out efficiently. The chief mistake made, in my experience, by junior medical officers in this respect, is that they do not begin their work in the right way. I will venture to indicate what I consider the right way, and, though I am by no means bigoted in the matter, I venture to think it is at least as good as any other. The first thing to be done is to learn geography. The medical officer should first of all procure a plan of barracks and get the general arrangement of the different buildings into his head. Having done this he must next study their position on the ground. Within one month he should know every building and its object by heart. This does not seem much to ask, but I have known medical officers who after a much longer period than the above have been quite astray in barracks if brought into them from some un-

familiar direction. After studying the map and the barracks themselves, the medical officer should then proceed to study the drainage and water-supply systems, inch by inch. He should personally go into every water-closet, test the flush, trace the connections with the soil-pipe, and of the soil-pipe with the drain. The line of the soil-pipes should be traced, and the position of its upper end relatively to the nearest windows noted. The next step will be to follow the course of each drain, inspecting and noting the position of and reason for every manhole, and having the lid off to see if there are any signs of blocking on the benching. The exact position of all ventilating openings should also be noted. The survey of the drain will proceed till the last disconnecting manhole is reached, and will not be completed till the medical officer has ascertained that the lid is on the opening into the cleaning eye.

In the same way the medical officer should trace the water-supply from the point of collection through the system of distribution and purification to the stand-pipes in barracks. He should make it his business to know the exact tap from which the men of any particular company are in the habit of getting their water.

The whole of the barracks should be studied in the same meticulous manner until the medical officer feels that as far as the construction of the barracks is concerned he is thoroughly acquainted with every detail of the soldier's surroundings. Until he is in that position he cannot possibly pretend to know anything about the sanitation of the barracks, since it cannot be too often repeated that sanitation is merely a means of adaptation to surroundings. Such an accurate knowledge of the mere bricks and mortar is the essential basis of all sanitation, and is not beyond the reach of even the dullest officer. Without such knowledge the most brilliant may come to hopeless grief. The closest laboratory acquaintance with the different varieties of the members of the coli group is of little use to the sanitary officer who does not know the position and condition of the barrack manholes, and the possession of the former item of knowledge is no excuse for ignorance of the latter piece of information.

Having acquired the knowledge of geography already

alluded to, the medical officer will be in a position to speak authoritatively with regard to the maintenance of sanitation. He should in future make a weekly inspection of barracks, and he will be wise if at each inspection he directs his attention particularly to some one or other main "surrounding." One week the drainage, another the water-supply, on a third the ventilation, will occupy his attention. By this I mean that on each of these occasions he will look thoroughly at some one system as a whole, giving a general "look round" only as regards the remainder of the barracks. In this way he can best avoid falling into the habit of a mere perfunctory stroll round the barracks. As long as everything is seen thoroughly once a month, not merely glanced at four times, he will fulfil not only the letter but the spirit of the Regulations.

Inspection of Men.—The Regulations lay down that the medical officer in charge of effective troops "will also inspect the men under his charge monthly to satisfy himself that their personal hygiene has been attended to." The system that I myself practised in this matter was the following: On being placed in charge of a unit, the first thing to do is to go through all the Medical History Sheets of all the men of the unit. This will take about five hours, and can be easily managed in the course of a week. A list should then be made of all the men who are the "weak points" of the unit, the men who have had enteric fever, repeated attacks of malaria, bronchitis, venereal disease, dysentery, etc. A separate list should be made out by companies of these men, and this list should include every man who has been in hospital within the last twelve months from any cause whatsoever. The first thing that will strike the young medical officer will be the large number of men who have never been "sick" during their service. He will realize that the real invalidity of the unit resides in comparatively few men. These are the men on whom he has to keep his eye. In the same way as he directs his attention to some particular part of barracks on any particular day, so he should make it his business to see and keep in touch with the "weak points" of his unit week by week.

I would also advise the young officer to keep a private weekly return indicating the condition of his unit. This

return should show by companies, squadrons, or batteries the actual number of admissions during the week, under a few broad headings only. This should form, in fact, a current account of the health of the unit. The undue occurrence of some particular cause of inefficiency affecting only one portion of the unit may thus be recognized, and the cause perhaps removed. The medical officer should keep constantly in mind that he is "in charge of effective troops," and it is his business to keep in just as close touch with the man in the ranks as with the man in hospital. He should try to look on every admission to hospital as an instance of failure on his part, until it is shown to be the contrary. General and other officers are apt to look on full hospitals as a sign of activity on the part of medical officers. One such, a short time ago inspecting a hospital and finding it almost empty, said to the medical officer in charge, "You don't seem to have much work to do," to which the other replied, "On the contrary, it is because I do so much that there are so few sick to show." A full hospital is the *opprobrium medici* of the army, and in nine cases out of ten it is full because medical officers fall into the error of thinking that their duty is to the sick man first and the healthy man second. The contrary is the case. The healthy effective man is the most important individual, and the greater the number of these the greater the efficiency of the army. This is of course a commonplace. I do not think, however, that medical officers recognize sufficiently that it is their first duty to see that the number of effective men are kept as high as may be. Sanitary duties are very apt to be pushed into the background, and allotted to any officer "in addition to his other duties." The first duty is that of preventing sickness, the second that of treating it.

> "This oughtest thou to have done, and not to have left the other undone."

There is plenty of room for the second after the first has been done; the performance of one by no means involves the neglect of the other.

CHAPTER XVI

TEMPORARY HABITATIONS OF SOLDIERS

As opposed to barracks, we have those temporary habitations which are occupied by soldiers when it is impossible or inconvenient for the authorities to provide them with permanent accommodation ; these are camps, bivouacs, and billets.

The occasions when such temporary accommodation becomes necessary occur both in peace and war. In peace, in our own army, bivouacs and billets are never resorted to ordinarily, except in the case of bivouacs for short periods on manœuvres. Billets are commonly used by foreign nations, both on manœuvres and also during the ordinary movements of troops in peace-time. So far their use has not been practised by us, except occasionally in an experimental fashion, as during the Cavalry Manœuvres in 1910. In the wars which the British Army is accustomed to engage in, the opportunity for this form of accommodation has not as a rule arisen, but in any campaign in a civilized country it would undoubtedly be resorted to. Our knowledge of the conditions is, therefore, drawn entirely from foreign sources, and cannot be regarded as having any first-hand authority. It may be permitted me to point out that where practical knowledge is so entirely lacking, the necessity for theoretical study is all the greater.

Camps may be either permanent, or, as they are sometimes called "standing camps," or temporary. The former are largely used in time of peace for instructional purposes—*e.g.*, for musketry and artillery practice—and in war at the base and at permanent posts on the lines of communication. The great Napoleon expressed himself very strongly on their dangers, from the sanitary aspect, in the maxim, "Tents are injurious to health ; a soldier is best when he bivouacs."

This statement contains a considerable amount of truth, though I venture to think it is founded on a similar fallacy to that which lies at the basis of the theory that "barracks are a necessary evil, the dangers of which we may hope to minimize, without expecting ever entirely to do away with them."

Camps and bivouacs differ from barracks most obviously in that they offer a less amount of shelter from the vicissitudes of wind and weather than the more permanent buildings afford. It would appear obvious, therefore, that the attendant evils, if any, would be greater in proportion as the protection was diminished; greater, therefore, in bivouacs than in camps, since in the latter the man has at least one or more folds of canvas between him and the outer air, whilst in the former the roughest shelter only intervenes. If we consider the individual man under canvas, there is not the slightest doubt that, given plentiful food, it is just as possible for him to maintain his health in a tent as when living under a roof, even when exposed to considerable extremes of heat and cold. British officers, who have probably a larger acquaintance with camp life than those of any other army, know that three or even six months spent in an 80-pound tent close under the Himalayan snows conduce in the majority of cases to the very extreme of health and vigour, even in men who start on their trip decidedly on the wrong side as regards their physical exchequer. The dangers of camp life, if such there be, are therefore not connected in any way with the individual life, and we are perforce driven to the conclusion that here again, as in so many other instances, the controlling sanitary factor is the communal life of the soldier. This, in my opinion, is the true solution of the problem, and if we are to minimize the evils of military camp life we must approach the question from this direction.

If we look at the difference between camp life and barrack life, we see that, from the communal point of view, the chief differences are that in the former case the men are crowded together on a smaller area of ground, and also that there are no organized arrangements for the removal and disposal of waste matters. Let us consider these in the above order.

Overcrowding.—This affects men in camp in two ways. In the first place they are concentrated in the daytime on a comparatively small superficial area; and, in the second, during the night hours they occupy tents which give them an amount of cubic space ridiculously small as compared with that which they enjoy in barracks. The former defect applies also to bivouacs, though the latter is absent unless the men are huddled up, as is the rule in foreign armies, in *tentes-abris*. The overcrowding in daytime is easily minimized by turning the men out of camp, either for military exercises or recreation. And here I may recall the saying of Sir John Moore, already quoted in the chapter on Physical Training, as to the evil of allowing the soldier to "lounge the whole day in a barrack, where the air cannot be good, and where, from indolence, his body gets enervated and liable to disorder." Lounging in a tent is quite as bad as lounging in a barrack-room. The defect of overcrowding at night is less easily dealt with, especially in cold weather. It is more than anyone has a right to ask of ordinary human nature to expect men to sleep on the ground with the tent-flies rolled up, and it is difficult to ventilate the roof of a tent without at the same time permitting the entry of rain. Honestly, I think the evil must be accepted, and if the man must breathe more or less fœtid and foul air for, say, eight hours of the twenty-four (during which, it must be remembered, the vital processes are less active than during the remaining sixteen), it is all the more necessary to see that for the whole of those sixteen, or as many of them as the weather will permit, the tent is aired by being struck, or at the least by having the flies or walls rolled up, and the men made to spend as much of the time as possible in the open. I need hardly say that the nightly overcrowding is enormouly exaggerated in bivouacs where *tentes-abris* are in use.

Removal and Disposal of Waste Matters.—It is in regard to this department of sanitation that the greatest danger of camp life consists. Obviously, too, the danger is the greater in direct proportion to the strength of the force and the length of time that the camp is occupied. It is far greater, therefore, in standing than in temporary camps. In respect of this matter I should lay down that a standing camp is any camp which it is known will be

occupied for more than a fortnight. That period is the longest during which it is at all justifiable to rely on a trench system of latrines. In all camps occupied for longer periods some permanent form of bucket latrine must be instituted, and the general directions which I have already given for the conduct of such latrines when discussing these installations followed. Removal is also a difficult operation. At a base camp a light tramway should be built to run all solid excreta to a safe distance, where they can be buried or thrown into the sea, or any large river not in use for debarkation purposes. Incineration *in situ* may be practised, and is probably the best method of all. In fact, the conditions must be assimilated as far as possible to those of a cantonment where a water-carriage system is not available, which are discussed in the chapter devoted to that subject.

The urine presents an even more serious difficulty. At the risk of repetition it may be stated that the great difficulty is the enormous bulk of fluid present compared with the small amount of putrefiable solid matter. If the former, averaging 40 ounces per man, could be disposed of, the latter, at the outside 3 ounces, would present but little difficulty. At the same time urine is an extremely dangerous fluid, at least potentially, seeing that enteric " carriers " frequently pass the germs of that disease by millions in this excretion. I say at once that, in my opinion, the removal by any purely mechanical means, such as by hand and cart, of this bulk of fluid (250 gallons for one battalion) without slopping is a practical impossibility. If local incineration is practised in the case of the solid excreta, then the urine can, by means of suitable apparatus, be evaporated and destroyed in the incinerators. The problem is, however, in practice, one of considerable difficulty. If incineration cannot be carried out locally, or if the pattern of incinerator adopted does not permit of the easy evaporation and destruction of the urine, then I see no way out of the difficulty except that of disposal underground *in situ*. This sounds, I am aware, a most insanitary proceeding, and a defence of this proposal is therefore demanded.

We have two things to guard against : one is the causation of a nuisance as a result of the decomposition of urea, with

the formation of carbonate of ammonia, the other the spread of infection. Presuming that leakage into the water-supply is precluded, which should always be done by the selection of a source of water at some distance from the camp (this step is, of course, imperative for other reasons than that with which we are at present concerned), the only means by which infection can be disseminated from the urine is the common fly. If the urine is made to run at once to the bottom of the pit, as in the pattern of urinal shown in Fig. 6, there should be no possibility of flies getting access to it through the overlying mass of stones, etc., with which the pit is filled in. The water would be disposed of by means of percolation and evaporation, and any possible nuisance could be easily abated by burning a certain amount of rubbish on the surface of the filled-in pit. The ashes resulting from the incineration would act as a further deodorizer. In fact, it would probably not be difficult to combine the urinal and the destructor in one construction, if a little care were taken in the digging of the pit. It would be necessary to protect the pit from flooding by surface water in heavy rain, and in very rainy climates by means of a canopy roof. I am certain that some such arrangement would be far preferable in a standing camp, even if occupied for months, than the inevitable slopping which must result from hand- and cart-carriage.

All waste matters, other than excreta, if of a dry nature, must be burnt. It will probably be necessary to construct a large permanent destructor to deal with the great accumulation of horse litter, carcasses of animals, slaughter-house offal, etc., that is the inevitable corollary of a large concentration of troops or a permanent camp. In some cases a portable incinerator, such as the Horsfall, may be found convenient.

The ordinary daily rubbish of units is best disposed of in local incinerators such as are described in Chapter XII. This is far simpler and safer than carrying it to a central installation. Slop-water from ablution benches must be disposed of by irrigation, and, if possible, under-drainage. The keynote of camp sanitation is conservancy. I do not say that, having disposed of your waste matters, you can sit down with folded hands and go to sleep. By no means ;

there are many other things to attend to. But I do say, with the very greatest emphasis and the firmest conviction of being right in saying it, that unless conservancy is recognized as being the most important task, much more if it is allowed to fall into neglect, no other sanitary measures that can be adopted will be anything more than mere tinkering.

The site of a camp is fixed either by military or sanitary considerations, or by neither. Many a camp has been selected by the mere haphazard choice of a tired commander, because water was handy and his men had done enough for the day. Gradually more units have joined, and eventually a standing camp has grown from the originally chance-selected spot.

Lord Wolseley lays down, in his "Soldier's Pocket-Book," that the choice of a camp should be made on sanitary grounds, when contact with the enemy is not expected within forty-eight hours. It not infrequently happens that a site originally selected on tactical grounds is afterwards used for permanent occupation. Unless there is chance of attack, as on the lines of communication, it may often be advisable to change the actual position of the camp from that originally selected. As a rule, the ultimate choice is a compromise. A site should, of course, be dry, gently sloping, but not too steep; conveniently situated with regard to water, but not too close to any large collection of water, especially in countries where malaria is prevalent. Virgin soil is better than cultivated. The nature of the vegetation is the best guide to the real condition of the soil; outward appearances are apt to be most deceptive. It is generally laid down that gravel or sandy soil is better than clay, but this is not universally true. It must be remembered that the dampness of the surface does not depend so much on the nature of the superficial layers of the soil as on the relation which these bear to the first impervious stratum below. A shallow layer of pervious soil lying on a very impervious one is far more likely to furnish a damp site than the impervious stratum itself. It is not infrequently the case that patches of gravel lie on saucers of clay; the former acts like a sponge, holding the water which is supported by the latter. Such a site may appear

outwardly dry, and in reality be damp even at the driest seasons.

Bivouacs.—The sanitation of bivouacs is precisely the same as that of camps. They are rarely occupied for more than a few days, and only in the absence of all means of shelter. Maugre the opinion of the great French leader, camps are not essentially worse than bivouacs from the sanitary point of view. It is, of course, quite possible that owing to bad management they may become so, but that is not due to any fault inherent in the system. An army that is unhealthy in camp will be far more unhealthy in bivouac, if it occupies the same ground for the same length of time in both cases. As a rule, when troops bivouac, they rarely stay in one place for two consecutive nights. They therefore march away from the site they have rendered insanitary, and thus escape the consequences of their own bad management.

Billets.—This term is used to denote the enforced quartering of troops on the inhabitants of the country. The conditions under which a billeting system must be carried on will naturally vary widely with the military position at the time. This will affect the length of time the billets will be occupied, and naturally also the degree of concentration of the men.

For prolonged occupation the area allotted to any large unit is calculated on the basis of the civil population. The capacity of any such area to accommodate troops will naturally vary with the nature and occupation of the inhabitants. An industrial community has less absorbing power than an agricultural, calculated on a population basis. Again, the number of men that can be quartered on any area will be smaller if subsistence has to be provided by the inhabitants than when it is furnished by the supply authorities. The Field Service Regulations lay down that under the former system, commonly called "billets with subsistence," a given area should be able to support a force equal to twice its normal population for one week. In billeting without subsistence a rich agricultural district can accommodate troops at the rate of 10 per inhabitant, whilst on an industrial district or town only half that number, roughly speaking, can be quartered. As regards

the number of men that can be placed in any house, the "Field Service Pocket-Book" lays this down at two men per yard of length for every room between 15 and 25 feet in breadth, and three men per yard if the room be more than 25 feet broad. The French allow about 400 cubic feet per man, or from three to six men per hearth.

In close billeting, when troops have to be concentrated in the immediate prospect of contact with the enemy, no rule can be laid down. Those men who are unable to find shelter under a roof of some kind must bivouac, but every roof will in all probability be used in emergency, since, as Lemoine observes, "the most detestable billet provides a better shelter against bad weather than the best bivouac." This rule would undoubtedly be observed, even at the expense of the existing civil population, should occasion and the weather demand it.

The sanitation of billets must obviously vary indefinitely according to the actual circumstances. In prolonged billeting, such as might be resorted to in the pauses of a campaign, the greatest precautions should be taken. Naturally, the first pre-occupation of the sanitary officer will be the health of the civil population, especially in respect of the prevalence of exanthematous or intestinal disease. The actual procedure to be followed will depend on the exigencies of the case. Theoretically, any locality where enteric fever, scarlet fever, measles, or diphtheria has lately been prevalent should be closed to billeting. It would but rarely happen that this could be done, and in that case the infected houses only need be avoided. Even this might be difficult as a permanent arrangement, and therefore all such houses should be made available for occupation by thorough cleaning with disinfectants, all unnecessary furniture, hangings, etc., being destroyed by fire. In the case of troops billeted only for one night in a town, it would be impossible probably, in a foreign country certainly, for the sanitary officer to ascertain in time all the houses where infectious disease had occurred. He must simply do the best he can. In the case of a campaign in this country it would be possible to rely on the local Public Health medical officers, many of whom are on the *à la suite* list of the Territorial Force. Such officers should be able

to furnish a detailed statement of all infected houses in their district to the commander of any British force moving through it. Water-supply in the case of large municipalities or urban districts would present no difficulty. In smaller areas, where no central supply existed, special arrangements would have to be made, just as in the case of troops under canvas.

Much the same rule applies to the case of removal and disposal of waste matters. In villages and scattered hamlets it would be necessary to construct extra latrines, outside the local boundary, of a temporary or permanent nature, as might be advisable. It would probably be a necessary, or at least a wise, precaution to place the entire village conservancy under military authority, especially in the case of prolonged occupation. Local labour would, of course, be used. In large villages or towns supplied with a water-carriage system of removal, it might be necessary to construct additional latrine accommodation, and connect this up with the existing drainage system. In all cases the local sanitary machinery should be interfered with as little as possible, and the sanitary officer must keep in as close touch as possible with the local Medical Officer of Health, more especially in this country. It must be remembered that as long as the troops are living intermingled with the civil population the health of the one cannot be considered apart from the health of the other. Any unnecessary dislocation of the regular peace-time machinery can only lead to bad results.

CHAPTER XVII

CLOTHING

THE object of clothing is much the same as that of habitations—namely, to protect the wearer, or in-dweller, from variations in temperature, more especially in the direction of increased cold, and from moisture. An extra complication is, however, introduced by the fact that the outward aspect of the individual is directly affected by his attire, and æsthetic considerations have therefore—unfortunately perhaps, but certainly inevitably—more weight in deciding wherewithal a man shall be clothed than in fixing the type and arrangement of his habitation. This is a point frequently overlooked by enthusiasts, and this is the reason why the well-meant efforts of certain would-be reformers inevitably come to grief. Any clothing, however sound the scientific basis of its design, is inevitably doomed to oblivion if it renders the wearer ridiculous or even conspicuous amongst his companions. Dealing with uniforms which have an historical connection, it is above all things necessary to remember that purely sanitary considerations can in no case be allowed to take a paramount position, and this is, of course, more particularly the case with those orders of dress which are intended to be worn on occasions of display or ceremonial, where historical associations are of such great importance. As regards service uniforms, this is not so much the case, but invisibility, which is so valuable in preventing injury, must be looked on as being of equal value with those factors which come into consideration in connection with the preservation of health. I do not propose to discuss here the question of uniform generally, but only of those uniforms which are worn in the field.

PROTECTION FROM COLD.—Clothing protects man from cold partly by reason of the non-conducting nature of the

actual fabric, but even more importantly as a result of the non-conducting nature of the air which is (1) occluded in the actual substance of the material, (2) enclosed between the different garments worn, and (3) which lies between the innermost garments and the skin.

Materials Used.—The materials most commonly in use for the manufacture of clothing are wool, silk, cotton, and linen. Occasionally the actual skins of animals are used, with or without the hair naturally growing on them. Leather, however, is only used for the lining of special garments, whilst fur hardly enters into considerations in connection with uniforms.

The various materials differ considerably in their relative conductivity. Thus, taking the conductivity of air as 1, that of wool would be represented by the figure 6·1, that of silk by 19·2, while cotton and linen would stand at 29·1. In other words, wool conducts heat six times as rapidly as dry air, silk three times and cotton and linen five times as rapidly as wool. Clearly the question as to whether a particular fabric will or will not conduct heat rapidly must depend to a preponderating extent on the amount of air in its meshes, and also on the freedom of movement permitted to that air. These two factors are decided entirely by the method of manufacture. As between different garments, those which prevent free movement of air and thus imprison layers of that non-conductor will be warmer than others which, whether by reason of their looser texture, or the way in which they are worn, permit of the free circulation of that medium.

The amount of air occluded in any fabric depends, as already stated, on their method of manufacture. It varies from 50 per cent. of the total volume in close-woven clothes to about 90 per cent. in the case of flannels. This capacity of retaining air depends partly on the degree of compression to which the material has been subjected, and partly on the natural elasticity of the fibres of which it is composed. Wool is the most elastic of the fibres in common use, linen the least. Thus a woollen garment is warmer than one made of linen on two accounts : first, because wool is naturally a worse conductor than linen ; and, secondly, because, owing to its elasticity, the resulting fabric is more spongy. The

power of retaining air is much affected by moisture. The amount of moisture that a material can take up is dependent largely on the hygroscopic nature of the fibre. Wool is more than twice as hygroscopic as linen or cotton, and when a woollen garment is soaked and then wrung out a large amount of moisture is retained in the actual fibre. The air spaces are thus left free. In the case of the two vegetable materials the water obliterates the air spaces and thus robs the fabric of its chief non-conducting quality.

The air between the different layers of clothing depends partly on the looseness of the fit and partly on the nature of the surface. Loosely-fitting clothes permit of the free movement of air, and, therefore, unless the various openings —at the neck, wrists, and ankles, for instance—are closed up, such garments tend to be chilly. Here again woollen materials show a superiority over the smoother linen and cotton fabrics. Fabrics which hold a great deal of water in their meshes are apt, when wet, to cling to each other, and also to the surface of the body. In this manner not only are the air spaces in the material itself occluded, but the layers of air between the different articles of clothing are also abolished.

Effects of Moisture.—When any cloth is saturated with moisture, the first effect is, as already stated, to increase its specific conductivity as a result of the occlusion of the interstitial air spaces. A secondary effect is produced by evaporation. Fabrics which are composed of non-hygroscopic material permit of more rapid evaporation, and therefore of more rapid cooling. This is a disadvantage on all occasions except in very hot dry climates, in which the non-hygroscopic material allows of the rapid evaporation of perspiration, and therefore imparts a sensation of coolness. In hot damp climates the sodden garment is irritating to the skin, and in all cold climates the rapid evaporation in dry weather and the increased conductivity in moist seasons conduce to chill.

The actual clothing of the soldier consists in part of that which is supplied by the State, and in part of that which he himself purchases. The former includes all articles of uniform and the requisite minimum of underclothing, and it is these articles alone that I intend to consider here. Night

clothing is not supplied except to British troops in Hong-Kong and some other stations. This supply is no doubt highly advisable on grounds of general cleanliness, and therefore indirectly on those of health. Whether it is imperative that the State should supply such articles at its own charges is a matter of question. The State is bound to supply all such articles as it considers absolutely necessary to efficiency, as well as those whose pattern it rigidly prescribes. It does not appear to be obvious that it should be called on to furnish other articles which do not come into the category of "absolutely necessary," but only into that of "highly advisable." In making suggestions as to clothing of troops medical officers should be careful to recognize the distinction. They should also remember that the subject of clothing is just as happy a hunting-ground as that of dietetics for the faddist. The healthy man can observe just as wide a latitude in the one as in the other, and the trade-mark of the valetudinarian is a meticulous particularity in either. The soldier is *ex hypothesi*, and also, in fact, a healthy male adult, and it is absurd to carp at details of his clothing because they do not correspond to the self-imposed dicta of fanatics.

Underclothing.—This consists of shirt, drawers, and socks. The shirt is in our army a woollen shirt of medium thickness, and the German winter shirt is not dissimilar. The United States enlisted man is supplied with two flannel shirts of very superior quality, but different thickness. They are provided with turn-down collar and breast-pockets, so as to give them a more "dressy" appearance when the jacket is not worn. In the majority of cases, however, the shirt is of cotton and extremely coarse. In India men often purchase cotton shirts made from a material called "twill lining." This is manufactured from the short staple Indian cotton, and, owing to its somewhat rough surface, is free from the ordinary objections of cotton shirts. I have known medical officers object to these being worn, founding their opinions on the well-known drawbacks possessed by long staple cotton garments. This is a mistake. As already stated, the quality of any cloth, *qua* its powers of retaining air in the meshes of the fabric, depend far more on the method of manufacture than on the material of which it is made. The short staple cotton

material is considerably looser than the cotton with which we are familiar in this country, and forms an excellent fabric for shirts. They are much less irritating than flannel shirts, unless these are of the very best material, and therefore beyond the purse of the soldier, and in seasons when prickly heat is rife should always be permitted.

Socks are issued in our own, the Japanese, and the United States Armies ; but on the Continent the soldier is expected to buy them for himself. The Japanese sock is heelless, and made of cotton in time of peace ; woollen socks were, however, issued in Manchuria. In some Services, but not all, " foot-cloths " are supplied. Socks are undoubtedly good when they are good, but cheap socks rarely are. There is no fault to be found with our own woollen sock, except those which are common to all footwear of this nature. The chief defect, inherent in the article, is the fact that the same part of the sock is always in contact with the same part of the foot and the same part of the shoe or boot. Certain areas are, therefore, always exposed to pressure and friction, whilst others escape. Wear is in consequence uneven, and the very best socks show breaches of continuity over heels and toes after not many days' continuous wear. A certain amount of relief can be obtained by changing a sock from one foot to another, but though this delays the inevitable end, the ultimate " hole " is all the larger in consequence. For the same reason the same parts of the sock always tend to get sodden and hard, and react on the same areas of skin. " Wearing out " can, no doubt, be postponed if care be taken always to change the socks, and never march two days running in the same pair. Careful kneading of the hardened patches and the removal of dirt after drying can also do a great deal to lengthen the life of the sock ; but the ultimate end is the same : washing will only hasten it. A sock which, even if carefully looked after, can survive a week's continuous " marching " use, or a fortnight's wear on alternate days, is undoubtedly rare. The life of a sock may, in fact, be placed at sixty to seventy road-miles. Even then, if skilfully darned, the sock may still be a serviceable piece of footgear, as most of us know from practical experience. Unfortunately, the soldier does not, as a rule, shine as a mender, and the rough patch that

is all that the average man is able to achieve is only one degree better than an actual hole.

On the other hand, a foot-cloth, if made of soft and absorbent material like flannelette, has many advantages. Being a mere piece of cloth about 12 inches square, it is much more easily cleaned and dried than a sock. The wear does not attack repeatedly the same part of the material, since the cloth can be applied to the foot in four different ways for each surface—that is, eight in all. There are no crevices, and, greatest advantage of all, in comparison with the cheap sock, there are no loose tags of wool left over in the finishing off. The best foot-cloth is no doubt worse than the best sock, but any foot-cloth at all is better than a bad sock. In the case of the regular soldier at the outset of a campaign there is nothing to be feared. His two pairs of socks should carry him 150 to 200 miles with plenty of care and a little mending. When it comes to replenishing, it is as well to remember that a foot square of flannel or flannelette is a very excellent substitute if fresh stores of socks are not available. I am aware that my opinions on this matter are somewhat at variance with those of military sanitarians generally, and I hold them as the result of personal experience lasting over 600 miles, more or less, on the rough footpaths of the Himalayas and Ladak. I am alive to the fact that ordinarily there are few things more misleading than individual experience when a general rule has to be formulated, but the fact that my own feet are peculiarly tender inclines me to be more confident in this particular instance.

Boots.—The general rule in all armies is to issue an ankle-boot. The Germans and Russians still adhere to the long knee-boot, which can confidently be stigmatized as the worst infantry footgear in the world. A mere sight of this cumbrous article is enough to remove all surprise at the tremendous list of casualties which the German Army showed from feet injury during the earlier days of the Franco-German War. The best of all military boots is, in my opinion, our own. The American boot is more highly finished, and the leather of the uppers more supple ; it is also, probably, very much more expensive. Having used our own boot on several occasions, I can confidently

say that for the price it would be impossible to get a better boot for rough walking, where appearance was no particular object. The United States boot till quite lately used to be too long in the ankle, and was provided with lace-hooks, which are anathema. They undoubtedly facilitate lacing as long as they maintain their shape, but they are apt to exercise painful pressure on the ankle.

It is, of course, an axiom that the boot should be fitted to the foot, and not the foot to the boot. This fitting must be done partly by the bootmaker and partly by the wearer. The former fitting is, of course, a question of manufacture, the latter a question of "breaking-in." The former concerns the sole of the boot, the latter the uppers. If the soldier had invariably a normal foot, it would no doubt be possible to build a number of boots all possessing a normal symmetry of form, and differing only in shape, some one pair of which would fit absolutely some one pair of feet. By having different "sizes" as regards not only length, but breadth, a considerable range on either side of the ideal normal can be accurately fitted. Unfortunately, the soldier comes to us with the character of his foot already warped by fifteen or more years of wearing cheap ready-made boots, and it is impossible to do more than fit his feet approximately, unless each man is to have a last specially made and retained for him personally. As regards original manufacture, the "fitting" consists in giving the man a boot the sole of which is large enough to contain his foot, spread under the weight of his body, with a small margin. The size and shape of this can be ascertained by drawing the outline of the foot on a piece of paper on which the man stands, the cardinal points only being accurately noted. The "breaking-in" of the uppers can only be done by softening these thoroughly with oil (linseed oil or ordinary dubbing can be used for this purpose), and then wearing the boot on short walks or about barracks. It is sometimes recommended that the boot should be thoroughly wetted and worn in that condition, being afterwards packed with straw or oats, or placed on a tree till dry.

There is a great difference in military boots in respect of the relative thickness of the heel, of the sole under the instep, and again under the fore-part of the foot. The

following table shows the above measurements for the more important armies in centimetres :

	Heel.	Instep.	Front Part of Foot.
Great Britain	3·0	1·0	1·3
Germany	3·5	0·3	1·0
United States (old) ..	3·0	1·2	1 4
United States (new) ..	2·7	0·7	0·7
Italy	3·0	0·7	1·0
Japan	2·5	0·5	1·0
Russia	2·0	0·5	1·0
Austria	3·0	0·5	1·0
France	3·0	0·4	1·0

The obvious objection to the thick instep of the British and old United States boot is the fact that it makes them unyielding when first used. On the other hand, the support given, especially after fatigue has set in, is considerably greater than in the thin-soled German and French boots. I am strongly of opinion that it is the want of support to the instep, combined with the undue raising of the heel in the continental boot, that accounts for the prevalence of the condition known as *Fussgeschwulst* in the German Army, in which it seems peculiarly common. This condition, which is, in my experience, unknown in the British Army, and is not referred to by Havard, Woodhull, or Munson, as occurring in that of the United States, is, in the majority of cases, due to fracture of the heads of one or more of the metatarsal bones, though some cases may be attributed to periostitis, the result of concussion. The actual cause is, in the great majority of cases (131 out of 186, according to Tiedemann), overmarching. According to Casarini, the injury is due to loss of muscular support to the vault of the foot, the result of fatigue. Obviously, this condition would be aggravated by any mechanism which tilted the foot, thus bringing the weight of the body more over the front of the foot, and transmitting the shock directly along the axes of the metatarsals.

The boots supplied to some of the continental infantrymen have large hobnails in the soles. This is a mistake.

The hobnail inevitably "draws" out of the leather, and the resulting hole gives free access to moisture.

An ingenious suggestion was made in the *Journal of the Royal Army Medical Corps*, January, 1910, by Captain Bridges for the manufacture of boots with replaceable outer soles and heels. As soon as the original parts begin to show signs of severe wear they can be detached, and fresh heels or soles fitted. In addition, heels which are apt in the case of the majority of men to wear unevenly can be changed from side to side.

Gaiters of some kind or another are the general rule. The object of these is—partly, at least, to prevent the access of small particles of grit into the boot—a very important function. They also support the calf to a certain extent, and save the knee from the drag of the trouser, which, if that garment is wet, may cause considerable discomfort. We were for long alone in issuing the puttie, but Japan and the States have now adopted them. A gaiter is better than a puttie, if well made and fitted, and as long as it is new ; but, on the other hand, putties are better than cheap gaiters, which do not answer to the above description, as is generally the case with those issued to the rank and file.

Jacket.—The ordinary short jacket is universally used. As a rule, it is made too tight ; the more it resembles a loose blouse the better. Pockets should be large and roomy, and the skirt come well down over the hips. The collar is usually single, but in our army a roll collar is fitted. The chief point of importance is that the collar in front should not rise much above the sternal notch. If protection is desired above this level, a loose neckcloth is the most suitable garment. Buttons are, in the majority of cases, concealed behind a "fly," and this is certainly the best method. The colour of this garment varies from our own khaki to the German blue-grey. This, however, is almost entirely a military question. The jacket is the normal fighting garment, but in the French and Italian Armies the greatcoat, with buttoned back-skirts, is still used. In their present campaign in Tripoli the latter Service have adopted the short khaki jacket. It is understood that the French contemplate a similar change in the near

future ; at present khaki is used by them for colonial service only.

Trousers.—These are made, as a rule, to match the jacket, the French still adhering—for the present, at least—to the well-known red breeches In India these garments are commonly cut down to the shape of "shorts," leaving the knee bare. For a warm climate these are undoubtedly the most rational form of nether garment, as soon as the man has got his skin hardened to sunburn, and to contact with thorns and stones when working in rough ground and taking cover. It must be remembered that the Highlanders in South Africa suffered considerably from blistering in the popliteal space, as the result of having to lie in the prone position for hours under a fierce sun. It might be possible to build the trousers in such a manner that a flap could be turned down over the knee except when the man was actually marching. From a physiological point of view the kilt is the best method of covering the thighs on the march. The large open space left free for evaporation is of the utmost value in regulating the body temperature, and preventing an undue rise.

Greatcoats. — The Norwegian Army is the only one which entirely dispenses with a greatcoat, whilst the French and Italian Services rely on this garment as a general Service dress. These may be taken as representing the two extremes of opinion, whilst the ordinary practice of using the greatcoat as an emergency article of wear for cold or wet weather only constitutes the mean. The United States supply a poncho for service, but otherwise the general pattern in peace is similar to the civilian greatcoat. Personally I do not look on the greatcoat as a necessary garment in its present form. My reasons for holding this opinion are given under the heading of "Equipment," and need not be repeated here. The Norwegian substitute of a thick knitted woollen "sweater" seems to me much more workman-like.

Head-Dress.—The question of a suitable head-dress is one which has agitated the minds of military administrators since when the memory of man goeth not to the contrary. The question of æsthetics comes more prominently forward in connection with this portion of attire

than with any other, in consequence of the close proximity which it naturally bears to the face. From a sanitary point of view the object of any head-dress is to protect the head from cold and damp, and in warm climates to ward off the direct rays of the sun, and also to shade the eyes. Protection from direct injury by sword or rifle-butt is also considered in some cases, notably in the German *Pickelhaube* and our own helmet, which is a bad imitation thereof. Helmets are, however, the exception, and the general pattern is that of a soft cap, with or without a peak, such as the French and Italian *kepi*, or the Austrian *feld-kappe*. The Swedes still adhere to the old three-cornered cocked hat, whilst the American soldier wears a wide-brimmed soft felt hat of the type which the South African War made so familiar under the name of the "smasher" hat. This last head-dress is probably the best from all points of view for use in a temperate climate, since it affords sufficient protection from wet, cold, and glare, without being in any way objectionable in appearance. Like all other portions of the equipment of the United States soldier, it is of excellent quality. The question of the proper head-dress for tropical campaigning is one chiefly of protection from the direct rays of the sun, and of ventilation of the space between the scalp and the inner surface of the hat. Any such hat must be so fitted that it comes down at the side to a level with the external auditory meatus, and sufficiently low in front to shade the eyes without obstructing the vision. Behind, it must project well outwards and downwards to about the level of the coat collar. The rim of the hat where it rests on the head should be a false rim, separated from the real rim by a definite gap of about $\frac{1}{4}$ inch. In the substance of the canopy of the hat one or more ventilating apertures should be made. The head-dress should be as light as possible, and cork is probably the best material for this purpose. The weight of the hat should be taken by cross-straps running from front to back and from side to side, so as to avoid pressure on the temples. If the inside is lined with cloth, which it should be, this had better be yellow or red in colour. It is true that the actinic theory of sunstroke is not now widely supported, but, still, if only on the same principle as the French

Marquise said her prayers, it appears a reasonable precaution to take. The problem of a tropical head-dress is well solved by the present pattern of helmet issued to the British soldier abroad. This has had the best compliment—that of imitation—paid to it by the German Army, though the authorities have "improved" on the original pattern by the addition of a hinged "tailpiece," with a dependent cloth flap. It would be safe to predict that a few weeks' campaigning, especially in the rainy season, would effectually "dock" these helmets of their additions. For extraordinary heat, such as might be experienced in India during the hot weather, there is undoubtedly no headgear to compete with the Cawnpore Tent Club *solah topi*, made of thick pith. The cloth cover should be artificially waterproofed, or, if this is impossible, the pith itself should be painted over with Aspinall's enamel, to protect it from rain.

CHAPTER XVIII

EQUIPMENT

By the term "equipment" we mean all those articles and appliances which the soldier has to carry to enable him to perform the duties of his profession in the field. The nature, number, and weight of these articles will depend on many factors. First to be considered is weight. The soldier cannot carry more than a certain load and remain at the same time a fighting man; he degenerates into a pack animal. At the same time he must carry a certain amount, since, owing to the exigencies of strategy and tactics, occasions will arise when the possibility of a certain movement or manœuvre will depend on whether the individual soldier can make himself self-supporting as regards ammunition, food, and shelter during the time spent in the execution of the proposed plan. As regards this point, then, the weight of an equipment must be a compromise between what the commander needs and what the man can carry. In settling the total weight, the absolute and relative necessity of different articles must be taken into account; the material of which they are made will also be of importance. The soldier who can carry most, or he who can be content with least, will have a great advantage over the less capable or the less hardy. Again, those armies which, by the exercise of ingenuity, are able to devise an equipment that will supply the greatest number of needs at the least weight will also have an advantage over those whose authorities make the least use of modern invention in the application of new discoveries to the manufacture of ever lighter and lighter material. From the sanitary point of view the most important equipment is that of the infantry soldier, since he alone is directly affected by the weight it represents.

The question of the equipment of the infantry soldier, as it at presents exists in the majority of European armies, may be said to date from the era of the Napoleonic wars. Up till that time the importance of strategical mobility was not so clearly recognized, as later, under the influence of Napoleon, it came to be. The kit that the soldier carried appears to have been to a great extent his own business, and the baggage waggons carried as much as they could to supplement deficiencies. With the commencement of the new era, however, it became important to make the infantry soldier as far as possible independent of wheeled transport, the more so that the means of communication, in the end of the eighteenth and the beginning of the nineteenth centuries, were certainly no better, and probably not so good, as under the Roman Empire in the second and third centuries of our era. At the same time, owing to the comparatively short range of ballistic weapons in the old muzzle-loading days, tactical mobility—that is, rapidity and ease of movement on the battlefield—was by no means so serious a problem as it is now that the range of the rifle and the gun have so enormously increased. It was possible, therefore, to load the infantry soldier fairly heavily for the march, without hampering him excessively when he came to actual contact with his enemy on the field of battle.

The progress of later years has, however, brought a great change. Communications have improved more in the last hundred years than in all the previous history of mankind prior to the introduction of steam and railways. Strategical mobility has become largely a mechanical question. On the other hand, the demand for tactical mobility has increased enormously. The infantry soldier can no longer reserve his fire till his officer has had time to settle with the commander on the opposite side the delicate question of etiquette, as to who should have the honour of receiving the fire of the other, much less can he advance in parade formation till he can see the whites of the eyes of his opponents.

Already, at 3,000 yards, he comes under effective artillery fire, and at 1,400 yards under effective infantry fire. Consequently, from within a mile and a half to a mile of the position attacked all movements must be made with the utmost rapidity, and from one piece of cover to the next.

Nor is this all. The enormous size of modern armies entails extraordinary exertion on those troops which are far back on the column of route, if it is intended that they shall be present at the decisive moment. It may be necessary on occasion to place more than one army corps on the same road, so that the most distant troops will be from twenty-five to thirty miles in rear of those in touch with the enemy. This distance will have to be made up at the last moment in one forced march, or at the best in a march and a half, the troops from the rear perhaps having to go into action straight from the march without having any rest. Again, since the decisive battle or battles will probably take place in the opening weeks, or even days, of the campaign, the reservists who have been called up to fill the ranks will not have had time to get hardened, as in the old days, by a long period of route marching to the enemy's frontier. The clerk or the shopman will be called, untrained and soft, from the desk or counter, and thrust straight, with 50 pounds or 60 pounds weight on his back, to march to the sound of the cannon.

The problem of equipment is obviously one the solution of which cannot fail to have an important effect on the conduct of the campaigns of the future. The first point to be considered is the maximum weight that the ordinary man can bear; the second, the different articles which he must carry in the order of their relative importance; thirdly, the weight which each of these represents; and, lastly, which of these can or must be dispensed with, to enable the soldier to carry out the wishes of his commander without undue physical suffering or deterioration.

Total Weight that a Man can Carry.—Every additional increment of weight added to the load of a marching man increases the expenditure of energy per unit of distance. Up to a certain limit—about 66 pounds—the increase of energy expended is regular per unit increment of weight, so long as the load is distributed in such a manner as not markedly to interfere with equilibrium. This increase equals 4·5 small Calories per pound per minute. Any increase beyond 66 pounds entails a disproportionate expenditure of energy. Thus between 66 and 88 pounds the increase is about 6 Calories, and above 88 pounds 10 Calories

per pound per minute. These figures, which are taken from Zuntz and Schumburg's "Physiology of the March," must be taken as minimal, since want of training, fatigue, or injury, such as lameness, may cause an excessive expenditure of energy. In addition, if the weight be carried asymmetrically, the expenditure is multiplied threefold. It must be remembered that the soldier must keep his hands free for fighting and his legs unencumbered for active movement, while at the same time the respiratory movements of his chest must be interfered with as little as possible. This entails the placing of all the weight on the trunk, and the greater bulk of it posteriorly—that is, more or less asymmetrically in the sagittal plane. In addition, the most important weight of all, and the heaviest individual weight, the firearm, must be carried in one hand or on one shoulder. This weapon weighs about 4 kilos (about 9 pounds) as a rule, and in comparison with other weights must be held to represent three times that amount.

Clearly the total load should not go beyond that which fixes the limit of regular increase—that is, 66 pounds. But if we are to consider the rifle as making a threefold demand on the energy of the soldier in consequence of its asymmetrical position, obviously we must reduce this limit by 17½ pounds. This places the total weight which the soldier should carry at 48½ pounds, or, in round numbers, say 50 pounds. The above method of calculation is a rough one only, but it tallies fairly well with the limit laid down by Kirchner, and is in accordance with the observations of Zuntz. This load is rather over one-third the weight of the average infantry soldier.

It next remains to consider what articles the soldier actually must carry, and their relative importance. The following list gives the former information :

(*a*) Armament, including rifle, side arm, ammunition and pouches, cleaning materials for rifle, and entrenching tool.

(*b*) Personal clothing, including shirt, drawers, and socks, coat, trousers, putties or gaiters and boots, neck-cloth, abdominal belt, head-dress, handkerchief, identity disc, and first field dressing.

(*c*) Food, including unexpended portion of ration last

issued, reserve rations and water, together with the appliances for carrying or consuming these—viz., mess-tin, water-bottle with cup, haversack, and cutlery.

(*d*) Accoutrements, including knapsack, with belt and braces.

(*e*) Shelter, including greatcoat and shelter-tent, or *tente-abri*.

(*f*) Personal necessaries, including small book, spare linen, personal cleaning materials.

I have classed the above in the order of their relative importance, as that appears to me. Clearly clothing and fighting tools must come first. I am not aware that, except at the assault on Lungtungpen, the former has of late years been dispensed with, and the importance of the latter needs no explanation. The average weight of the clothing worn is about 13½ pounds. This cannot be reduced. The soldier has but the one suit, and it would be as dangerous to lower the weight—which could only be done at the expense of the thickness of the fabric—as it would be out of the question to increase it by supplying thicker material. The weight of the rifle, bayonet, and entrenching tool is also a constant, and these total up to 12 pounds 8¼ ounces. The British soldier carries 150 rounds of ammunition, weighing 9 pounds 13½ ounces. Some of the continental authorities are in favour of reducing the number of rounds carried by the man, and placing a greater number in the regimental transport. As Major von Schreibershofen points out, the number of days in which the soldier is occupied in emptying his pouches with the greatest rapidity are few compared with those on which he is marching with no chance of firing a shot, and since a portion of his ammunition is already carried for him in the regimental transport, it is merely going a step farther in a direction already to a certain extent taken. I do not understand that the opinion of our own Staff is at all likely to trend in this direction, and, speaking as an onlooker in this respect, it seems to me that this suggested reduction is merely one of those proposals so common in peace-time which fade so rapidly in war, all of which aim at increasing celerity of movement at the expense of striking power.

Taking the necessary clothing and fighting equipment

alone, we see that a definite and irreducible load of about 36 pounds must be placed on the soldier before he starts on a march.

After armament and clothing the next most important item in the load is food and water. These must be carried in certain receptacles, and these again must be fastened to the soldier's body in some manner, so that they can be laid aside whenever not absolutely needed. For this purpose accoutrements are necessary.

Taking water first, I explained in the section on marching that the soldier should be supplied on a long march with about 1 litre of water for every six miles after the completion of the first seven. The rational size of a water-bottle is therefore a litre, or $1\frac{3}{4}$ pints. This amount of water weighs over 2 pounds, and together with the water-bottle 3 pounds 10 ounces. The rations carried at present are the unexpended portion of the last day's ration (say $1\frac{1}{4}$ pounds) and the emergency ration weighing $9\frac{1}{2}$ ounces. The former is a nebulous quantity, but in all probability the entire amount of food altogether will not come to more than 2 pounds, if as much. To this we must add the weight of the mess-tin and haversack, etc. The total of food and water, together with the weight of the receptacles in which they are carried, will then amount to about 8 pounds.

As already stated, the soldier must be provided with certain accoutrements, consisting of belt and braces, to which the various weights that he has to carry may be attached. These weigh in our equipment 2 pounds 13 ounces, the weight of the pack being for the present excluded. The haversack is also indispensable and weighs, with necessary cutlery, 1 pound 5 ounces.

If we take the soldier, then, with merely his ordinary clothes, his armament, and his food for the day, we find that the weight he must carry is as follows, in round figures :

(*a*) Armament	$22\frac{1}{2}$	pounds.
(*b*) Clothing	$13\frac{1}{2}$	,,
(*c*) Food, water, and necessary receptacles ..	8	,,
(*d*) Accoutrements	3	,,

forming a total of 47 pounds. It is true that, by using aluminium instead of block tin or enamelled iron for the

mess-tin and water-bottle, we could save about 1½ pounds, but it is clear that even with this reduction it is impossible for a man to be self-supporting for one day as a fighting man unless he carries a load of at least 45 pounds.

The German and French soldiers carry less weight when reduced to this absolute minimum of fighting weight, the former carrying about 38 pounds and the latter 44 pounds. In either case the number of rounds carried is less, since the German soldier carries 30 of his 150 rounds in his knapsack, which, for the present hypothetical calculation, is supposed to be left behind.

Dealing with round numbers only, it may safely be said that the soldier must, to make himself supporting as regards food and ammunition, carry for one day's fighting at least 40 pounds weight. This includes no shelter for the night, no warm clothing (greatcoat, jersey, etc.), and no food beyond the remains of the ration issued the day before.

This leaves us with, at the outside, 10 pounds to provide for the above comforts, for any extra food and ammunition, and for those matters that are included under the head of "personal necessaries." There is not the slightest doubt in my mind that the extra food and the extra ammunition should be recognized as having the first claim on this margin of weight. It can be at once recognized that the limit of 6 pounds already laid down as the weight of three successive rations (see Chapter VIII.) errs if at all on the side of liberality.

The solution of the problem lies in distinguishing between the equipment that is absolutely necessary for fighting and that which is merely convenient on the line of march. This is to a large extent done in our new webbing equipment, and that of some Native regiments in India who have adopted the rucksack. The newly-sanctioned equipment of the United States, however, solves the problem in the most scientific and complete manner. In this, by merely undoing a few straps the soldier can free himself from the more cumbrous portion of his "kit," and go into action with merely his weapons, ammunition, food, and water.

Such a method, of course, anticipates that the soldier shall at certain times suffer considerably from exposure. This fact must be faced and the hardship minimized as far

as possible by keeping him well fed at ordinary times when no especial strain is inflicted on him.

The problem will present itself in its most difficult aspect in the opening movements of a great campaign. The soldier in the ranks is capable, on the one hand, of carrying his full load on the march if desired, and on the other of bearing the hardship of a few nights without shelter in the open, since he starts the campaign well fed and in good training. The reservist, who will almost certainly not be in good training, and may possibly, in some cases at least, be not too well fed, will neither be able to carry the load easily nor undergo the process of "roughing" with such equanimity as the serving soldier. Later, no doubt, he will acquire both faculties, but the general feeling seems to be that the decision will be arrived at in the first weeks, if not days, of the campaigns of the future, and it may well be that he will learn his lessons too late.

Method of Carrying Equipment.—The method of carrying the equipment varies in different armies, and is regulated by different factors. The most important, from a physiological point of view, is the extent to which the new load displaces the centre of gravity of the soldier's body. A load should therefore be arranged primarily as far as possible with regard to this aspect of the question : the only consideration that claims priority being that those parts of the soldier's equipment which directly concern his fighting activities, should be so placed as to be readily accessible when wanted. It would naturally be absurd to place his ammunition in such a position as to interfere with his getting ready access to it whenever needed. Again, the load must be so arranged that the movements of the soldier, especially those of actual fighting, whether with bullet or bayonet, shall be as little hampered as possible.

Arrangement of Armament.—The rifle is, of course, carried in the hand, either clear of the body as at the "trail," or at the "slope" on the shoulder. In some armies, as, *e.g.*, in the Austrian, special facilities are given for slinging this weapon on the shoulder, a small roll being placed on the outer end of the shoulder-strap to prevent the sling from sliding off. In the new French equipment this arrangement is, I believe, to be imitated. This slight

slight addition to the coat is, in my opinion, distinctly workman-like. The bayonet is carried almost invariably on the belt close to the left mid-axillary line. In the latest American equipment it is placed, during the march, on the left side of the combined haversack and pack, the upper end of the scabbard being level with the shoulder-line. In this case it can, however, though not very readily, be detached from this position and hung on the belt. This seems to me an unnecessary refinement. The weight of the side-arm is so small that the usual "hip position" appears to me free from objection. The ammunition is almost always carried in pouches. The bandolier was in use until lately in our own army, and still is in that of Russia. This method of carrying ammunition is the worst possible, from the physiological point of view. It hampers every respiration, and greatly impedes evaporation from the chest. Pouches are either rigid as in the German, Austrian, and Russian armies, or soft as in our own, and those of Norway and the United States. The objection to rigid pouches is that they press severely on the abdominal walls in the prone posture. The German pouch, carried in front, is, for instance, 3 inches in antero-posterior measurement. The leather of which the pouch is made is of excellent quality, but the whole apparatus is so extremely hard and thick that I cannot but think that in a prolonged fire-fight, as, for instance, occurred at the Modder River, when men were compelled to lie for many hours on their faces, serious injury to the abdominal organs might result. The Austrian and Russian anterior pouches are 2 inches thick, and are shaped so as to exercise less pressure. The French soldier carries two leather pouches in front, made of rather thick leather, and semi-rigid in construction; they are only 1 inch thick. The Norwegian pouch, of which two are carried in front, is made of soft, well-dressed leather of exceptional quality. It seems to me the best leather pouch in use. In our own and the United States Army, webbing is used, and we differ only in the arrangement. Thus, in our case the pouches are arranged in two "patches" of five, two above and three below, covering each hypochondriac region. (These "patches" are called "carriers," and are attached to the braces of the equipment, as well as to the belt; they

assist materially in taking the weight of the pack—see p. 328). In the United States' equipment the ten pouches are attached directly to the belt, five on each side. They thus lie more symmetrically with regard to the centre of gravity than our own. The difference is slight from the physiological point of view, the elevation of the weight above the horizontal plane in which that centre lies being comparatively small in the case of our upper pouches. The advantage, slight as it is, is, however, on the side of the United States' soldier. In case of extreme fatigue and consequent hepatic engorgement, the pressure of the thirty rounds carried in the upper pouches on the right side in our equipment might cause distress and hamper respiratory movements. From the military point of view leather is perhaps preferable to webbing, being less likely to alter its shape on account of wet. The rigid pouches of the chief continental armies can be defended on no other grounds. The pain that the rigid pouches of the Germany Army will inevitably inflict on the man who has to lie, for perhaps a long summer day, in the prone position on hard ground, will amount to exquisite torture, and lead inevitably to unnecessary movement and exposure. The Austrian soldier carries a large pouch on the centre of the belt behind. This is essentially connected with his knapsack, and assists materially in relieving the pressure of the braces on the axillæ. The French also have a posterior pouch (shortly to be abolished), and the Germans have dispensed with theirs. From the physiological point of view these pouches are good, as placing the weight much closer to the centre of gravity than is the case in the anterior pouches. The ammunition is, however, in an inaccessible position. The Germans have placed the thirty rounds which used to be carried in this pouch in two small pockets on each outer edge of the flap of the knapsack, in this way raising it above the centre of gravity, without placing it in a more convenient position.

The ammunition should be carried so as to be independent of all other loads, as, *e.g.*, in the ingenious arrangement of the Austrian Army, which renders it possible for the man to get rid of his knapsack, and all the accessories which that entails, without losing a round of single cartridge. Those of the Norwegian and German infantries, which make

such a rearrangement extremely difficult, seem to me on all grounds most unworkman-like.

The entrenching tool is slung on the belt in some cases (German, French), in other cases carried on the knapsack or pack (Norwegian, United States). In the former case the man is apt to be annoyed by the constant swinging of this heavy and cumbersome implement; in the other the position of so much weight so high above the centre of gravity is objectionable. On the whole it is better, I think, to have a comparatively heavy weight fixed than movable, even though the position may in a mechanical sense be somewhat faulty.

Food and Water.—The unexpended portion of the last ration issued is carried either in the haversack or the mess-tin; the reserve rations in the knapsack. The packing of these leaves a good deal to be desired in most cases, the United States only having adopted a really sensible method. In their new equipment, the hard bread is made up into "cartons," each measuring $7\frac{1}{4}$ by $2\frac{1}{2}$ by $2\frac{1}{2}$ inches, wrapped in paraffined paper. The bacon is packed in tins of approximately the same size, each tin containing two rations of bacon. Another tin, the condiment tin, also of the same shape and size, but with rounded edges, contains three rations of coffee, salt, and sugar. In this manner packing is considerably facilitated. In some Services the different items of which the ration is composed are carried loose in small cotton bags. Such an arrangement I cannot but look on as most unsatisfactory. The reserve rations are always carried in the knapsack. This arrangement makes it still more difficult to dispense with this weighty encumbrance, should the situation demand it. The problem is not an easy one to solve. If the rations are placed in the haversack, the weight is asymmetrically and clumsily placed, but I think that even this would be preferable to running the risk of the man losing his ration on account of the packs having to be left behind in a hurry. At least, as regards one ration, this should be placed in the haversack. Where travelling kitchens are in use, one or more reserve rations per man are carried in these. The water-bottle is usually carried suspended on the belt, but in the French equipment it hangs over the shoulder by a diagonal strap—a bad arrangement. In the

Austrian Army it is carried inside the haversack. The size of the water-bottle varies a good deal. Our own, containing 1¾ pints (1 litre), is the largest. The shape does not as a rule vary much from that of the ordinary flask, but the French *bidon* is quite distinctive in this respect. In addition to the usual opening for filling and drinking from, it possesses a secondary opening, of a calibre about equal to that of a quill pen, which is intended to facilitate the exit of water from the main aperture by permitting the free entrance of air. The material in use is in most cases aluminium, but the Italians still adhere to the old-fashioned wooden barrel-shaped bottle. There is a certain saving in weight in using aluminium, as compared, for instance, with enamelled iron, or block tin, and where, as in this case, every ounce is of importance, no saving, however small, can be despised. Using still our present shape of bottle, it should be possible to reduce the weight by about 14½ ounces. At the same time it must be remembered that the chief weight in the case of the bottle is the water it contains, not the metal of which it is composed, and in that direction I can see no opening for reduction.

Objection is sometimes made to aluminium on the grounds that these bottles cannot be used to hold cold tea. As a matter of fact, in some bottles this is the case, but the blame does not rest with the aluminium, but with the other metals with which it is alloyed, principally iron and copper. Pure aluminium, and aluminium and magnesium alloys, are not affected in this way.

In some cases the water-bottle is carried attached to the back of the knapsack or similar article of equipment. This is the case in some Native Indian regiments. As a result a weight of about 2½ pounds is suspended 8 to 10 inches behind the centre of gravity. The reason for this faulty position is that the bottle is out of reach, and cannot be used by the man except by order. In my opinion this excuse is not sufficient to cover the error in design.

In our army each man carries an individual mess-tin, and this is now the general rule. In some armies there are certain utensils common to several men, but carried, of course, by one only of the number. This seems to me an unnecessary complication, and the practice seems likely to be soon

universally abandoned. Individual mess-tins are usually made of aluminium, and always should be so. The only drawback to the use of the metal in this connection is the impossibility of using any alkali for cleaning purposes, and also the liability of the utensil to become indented. This last defect need no longer exist in view of the numerous hard aluminium alloys now procurable. The individual mess-tin is usually carried on the knapsack, strapped to the outside or on the top.

Shelter.—This consists in all armies, except the French, Norwegian, and Italian, of the greatcoat, and in all armies but our own of the shelter-tent as well. The French and Italians wear a greatcoat with buttoned-back skirts at all times, whilst the Norwegians issue a thick knitted jersey, called an "Icelandic jacket," together with a roomy canvas sleeping-bag. The Norwegians use in addition in winter a short jacket, called a *Vindjakke*. It is made of canvas, and is said to afford excellent protection against cold. There is little to choose between the different greatcoats in use. The German coat has a small linen hood attached to and folded inside the collar. This can be pulled over the head under the helmet, and thus keeps the collar in position to protect the back of the neck. All the greatcoats that I have seen are unsatisfactory. As long as a man is up and about they protect both his body and, *tant bien que mal*, his lower limbs as well. Immediately he lies down his legs are absolutely without any cover, and he benefits no more from the use of this cumbersome garment than if he had on merely the well-known "British warm" so much used in India. It is extremely suggestive, I think, that the Norwegians, who habitually manœuvre in snowy weather, have discarded the greatcoat in favour of a sleeping-bag. The chief objection to the latter would, I imagine, be on military grounds—the inevitable hampering of the soldier's movements in case of a night attack. I fancy that few commanding officers on the Indian frontier would care to have their men's legs shackled in this manner. A stout pair of overalls, such as are used for motor-cycling, or such as are worn by policemen on point-duty, would hamper the man's movements to the least extent, and, if combined with a thick pea-jacket, would afford sufficient protection.

The shelter-tent, or *tente-abri*, is carried in every army except our own. It consists as a rule of a rectangular-shaped piece of light canvas with hooks or buttons so arranged that two or more pieces can be fastened together to form a tent for a corresponding number of men. It is carried attached to the knapsack, either separately or, as in the German Army, rolled up with the greatcoat. In addition to the cloth, a certain number of small pegs, and in some cases sections of a jointed wooden pole, are also carried. In the Austrian and United States Armies it is intended that the rifle (with the bayonet fixed in the former case) shall perform the function of a tent-pole. This arrangement hardly seems workman-like, and might cause confusion in the case of an unexpected night alarm. The total weight of the tent with pegs and pole is considerable, and it is doubtful whether full value is received for this additional impost on the soldier. Our own experience, which as regards climatic exposure is greater than that of any other nation, decidedly points to the shelter-tent as being a luxury. The German Army did not use them in the Franco-Prussian War, in spite of the fact that the climatic conditions during that campaign were extraordinarily severe. On the whole, I think that the tent is rather more of an incumbrance than an advantage, and I find that I have the support here of General von Bülow, who says in his "Criticisms of the Campaign in Germany, 1806 to 1808," that "the protection against the weather which a linen roof affords is of less value as regards the health of the soldier than plenty of good food."

Necessaries.—Under this heading come the various odds and ends, such as change of shirt, etc., cleaning materials, small book, and in the German Army song-book, which are necessary to a certain extent to the soldier's comfort, but by no means so necessary as to justify their weight being placed on his shoulders. With the exception of a spare pair of socks, his toothbrush, and his small book, all the other articles classed as necessaries can be better carried in the transport. At such periods as the army is engaged in sitting still, or when the movement is one of little urgency, the soldier can have the benefit of these extra comforts. During the concentration before a great battle, or while actual fighting is going on, he must learn to

go without anything but the real necessaries—ammunition, water, and food. These alone will lay as great a weight on him as he can manage to carry, and still retain the activity which his task demands. These so-called necessaries are in themselves individually of little weight. The encumbrance which they entail is due to their number, and the fact that their presence entails that of a cumbrous receptacle—the knapsack, in which they are carried.

The Knapsack.—This still in the generality of cases retains the form of that carried in the Napoleonic wars—namely, a square, flat box, consisting of a wooden framework covered over with leather or canvas. This is supported either on braces which are connected both in front and behind to the belt, or else by leather loops which pass round the axillæ. The latter, the original form, persists, as far as I know, only in the French Army. The great drawback of this pattern is that the comparative shortness of the leather strap forming the loop entails danger of constriction of the large vessels and nerves of the axilla, with consequent œdema of the hand, and occasionally temporary paralysis of the muscles of the arm. It is on this account that it was condemned in our army about forty years ago. In the German pattern the knapsack is fastened by its upper edge to the shoulder-brace, while its lower edge is connected to a guy-strap, which leaves the brace about the level of the nipples. With a fairly deep knapsack all danger of the constriction complained of above is avoided, and in the Austrian knapsack this is minimized to an even greater extent by leading the guy-strap to the lower edge of the posterior ammunition pouch, which is itself an adjunct of the knapsack. At the same time this guy-strap, by throwing a portion of the weight on to the brace in front of the shoulder, reduces the backward drag of the knapsack, which would be much greater if it depended on the back of the brace only. In the Swedish Army a supplementary support is furnished by a strap attached to the middle of the upper part of the knapsack. The free end of this can be grasped in either hand, and by pulling on it the man is able materially to relieve his shoulders : an excellent device.

In the Norwegian Army a rypersack, or rucksack, is used instead of a knapsack. This sack, which is triangular in

plan, is supported on a wooden framework (*meis*) which fits to the back. The weight comes much lower down on to the loins than is the case with the knapsack, and the intervention of the framework prevents the pack from coming into close contact with the back, and thus obstructing the evaporation of moisture. Physiologically this rucksack has the advantage of bringing the weight closer to the centre of gravity, as well as of causing less interference with temperature regulation. In some Indian regiments (Gúrkha more especially) a rucksack is used without a framework, and is highly approved by the men of these units. In this case the rucksack can be thrown off with the greatest ease if no longer required, but in the Norwegian equipment the lower part of the sack is connected to the belt in such a manner as to prevent this. Where the sack is simply suspended from the shoulders it is very apt to jump about at "the double." For hill-work, however, it is thought very highly of, and, indeed, is the natural method of carrying a load practised by the Tyrolean and Alpine guides.

In the new webbing equipment which is in process of being issued to our Army the knapsack is replaced by a square canvas sack, which differs from the knapsack chiefly in not possessing any rigid framework. This is attached to the general framework of the equipment in two ways. At the upper corners of the pack are two suspension-tabs, which pass through sliding buckles on the braces behind the shoulders. From each lower corner a narrow supporting strap passes forward, to be attached by a buckle to a narrow "end-piece" connected with the posterior lower corner of the cartridge-carrier of the same side (see p. 322).

The essential point to remember is that the weight of the pack is, in the first instance at any rate, carried by the narrow end-pieces attached to the carriers, and *not* by the suspension-tabs at the top of the pack. The function of these latter is to keep the pack from falling away from the body. After a short time the weight of the pack slightly stretches the narrow end-straps of the carriers, the weight then becoming partly transferred to the suspension-tabs. If the whole or even the greater portion of the weight be allowed to be transferred to the suspension-tabs, the essential merit of the design is sacrificed.

The pack is easily removed from the rest of the equipment without removing the latter or undoing any essential portion of it.

The new equipment just sanctioned for the United States is a complete departure from anything previously used. The knapsack is replaced by a pack, which is supported on the braces at the back. When the shelter-tent, blanket, and poncho are not carried, this carrier or haversack forms an oblong pack lying along the spine from the level of the shoulders to that of the upper edge of the belt. Its contents are the reserve rations and mess-tin, with knife, etc., these latter being placed in a flap-pocket that closes the upper end of the carrier. When the tent, blanket, and poncho have to be carried by the man, they are rolled up in the shape of a thick sausage, which is fastened into the lower end of the above carrier. The whole now forms a long pack extending from the shoulders to the gluteal fold. The tent, poncho, and blanket can be readily detached from the rest of the equipment. It is intended that the man shall detach these articles immediately before becoming engaged, the only weight remaining being then his food and water, feeding-utensils, and armament. The entrenching tool lies vertically on the back of the pack. It must be admitted that this form of pack is the most satisfactory from the physiological point of view that has as yet been invented. The disturbance of the centre of gravity is minimal, and the area of skin occluded from evaporation by the pressure of the pack also made as small as possible. This is true, however, only of the fighting reduced pack. The full equipment, with poncho, blanket, and tent, has at first sight a cumbersome appearance. This may in part be due to its novelty, and experience obtained by actually carrying the load would be necessary before pronouncing finally on this point. Undoubtedly very careful packing would be needed. An early start from a wet bivouac would render this a matter of considerable difficulty.

The Russians do not as a rule carry a knapsack, their effects being placed in a large and cumbersome haversack slung diagonally across one shoulder. This practice, which has nothing to recommend it, was till lately the rule in the United States. In the Guard, however, a long black canvas

pack is issued, resembling somewhat in shape the new pack of the United States soldier. It does not possess any framework, and its position is physiologically better than that of the usual continental knapsack.

Necessity of the Knapsack.—Napoleon laid down the knapsack as one of the five indispensable articles from which the soldier should never be separated, the other four being his musket, ammunition, rations for four days, and entrenching tool. In the face of such authority it seems somewhat rash to question the absolute necessity of this article of equipment. The great drawback to the knapsack is the fact that it must be carried on the back, and, since the weight must be supported on the shoulders, high up on the back. The disturbance of the centre of gravity caused by the knapsack is greater than that due to any other portion of the equipment, partly on account of its absolute weight, and partly on account of its distance horizontally and vertically from the centre of gravity. The *raison d'être* of the knapsack is the necessaries, and, if these could be dispensed with, the knapsack could either be done away with or replaced by some such smaller article as, for instance, the fighting-pack of the American soldier. There is not space to discuss what the shape and size of such a pack should be, though the United States equipment gives a very valuable indication. It must be carried at the back, and supported on the braces ; it must be as little conspicuous as possible, so as not to attract fire ; and it must cover as small an area of the back as possible, so as not to interfere with evaporation of the sweat to a greater extent than inevitable.

CHAPTER XIX

PREVENTION OF INFECTIOUS DISEASES

An infectious disease is a disease due to a micro-organism which is capable of being transferred from an infected to a non-infected man, directly or indirectly, every fresh case of such disease being traceable, directly or indirectly, to a previous case of the same disease.

In every infectious disease, then, we have to consider three individuals or entities—namely, the infected man, the disease germ, and the non-infected man. These three form a chain, continuity of which is necessary for the occurrence of any fresh case of the disease, whereas prevention consists in severing that continuity.

The chain is continuous when the germ is able to pass from the infected to the non-infected man, and prevention, therefore, consists in preventing that passage. We have, therefore, to consider in the case of any infectious disease, the method in which the germ leaves the infected man, the means of transit by which it passes from him to the non-infected man, and, lastly, the method by which it obtains access to the body of the non-infected man. The above general principles are true of all infectious diseases whatsoever, and therefore the prevention of all such diseases must consist of action along similar, if not identical, lines. Moreover, since in a great many cases different disease germs do, as a matter of fact, use the same means of exit from and entry to the bodies of the two men concerned, prevention in these will be on identical lines. I will return to this point later.

Before going into these points it will be advisable to discuss the characteristics of the three different links in the chain of causation.

The Infected Man.—This individual, the first link in the chain, may be defined as "a man who harbours in his body, and continuously or at intervals sets free, the germ of an infectious disease." It is to be noted in the first place that the "infected man" need not be a "diseased man," using that word in the ordinary sense. He need not, that is, show any visible signs of the disease, and, moreover, he need not necessarily ever have shown such signs, or even ever have suffered from, or had, the illness himself. Under the term "infected man," then, we include not only the man in hospital or under treatment from the disease, but a large number of other men.

We may, however, divide all men answering to the definition given above into five classes as follows :

1. Men actually under treatment for, and recognized as suffering from, the disease.

2. Men who are suffering from the disease in a purely technical sense, the symptoms being so trivial that they pass unnoticed, and the presence of the disease is not recognized. These are commonly called "ambulatory" cases.

3. Men who, having had the disease, either in its recognized form, as in 1, or unrecognized, as in 2, continue for an indefinite period to harbour and set free the disease germs continuously or at intervals.

4. Men who, having never themselves suffered from the disease, have been in contact with men of any of the above classes, either as attendants or commensals, and, as a consequence, harbour and discharge the disease germs continuously or at intervals. The term "carrier" is usually applied to members of this and the previous class.

5. Men who are in the early stages of a typical attack before definite symptoms have developed, and in whom the disease is therefore not yet recognised. Ordinarily the period during which these men remain in this class is short, as they quickly develop into members of Class 1. It is recognized now, however, that men may harbour disease germs for periods much longer than those which are usually laid down as the "days of incubation," and as a result of some accidental lowering of their resisting powers, or some sudden access of virulence on the part of the germ, develop the disease.

The above classification is of importance from the point of view of prevention, since the members of the different classes differ considerably in the amount of danger which they represent. Obviously the danger from members of Class 1 is, or should be, very small, because it is known, and can be met. The same applies to members of Class 3, who have originally belonged to Class 1, and to members of Class 4, who have been in attendance on, or in close contact with, members of Class 1. Men who belong to Class 5 in the majority of cases rapidly develop typical symptoms, and the danger is thus limited in point of time. Obviously the most dangerous of all are the men who belong to Class 2, the ambulatory cases, or those "carriers" who have developed from being originally ambulatory cases, or, as a result of having been in close contact with them.

In the Service this is more true than in civil life, since our system of personal records enables us to keep track of all men who have suffered typically from, or been in close contact with, typical cases of any infectious disease, whilst our administrative powers enable us to control their movements. The danger in our case should therefore be only from the developing case and the ambulatory case.

One of the first steps, then, in scientific prevention of disease is early recognition of these cases, and in this respect a great deal of help may be anticipated from improved laboratory methods, especially in time of peace. I should like to point out, however, that it is not entirely a question of test-tubes and microscopes, useful as these undoubtedly are as aids to the solution of the problem. A very great deal will depend, more especially during war, on the personal equation of the medical officer in charge of the unit concerned, and the amount of confidence he is able to inspire in the men who come sick, and even more importantly into those who never come sick if they can help it.

The personal equation of the soldier is also important, especially on active service. A good-hearted man will bear up against an attack to which his less resolute comrade may succumb. He may complain of "being a bit off colour," to use a familiar and convenient expression, or may complain only of slight diarrhœa or headache. The problem of dealing with such men is one of the most difficult which

the young medical officer will be called on to face. Too stringent rules will defeat their own object, and merely encourage the faint-hearted and malingerer. At the same time they will deter the good man from seeking that assistance which might, by tackling the comparatively trivial complaint that affords the micro-organism of serious disease its loophole, ward off an attack.

The object of sanitation in the army is to keep the ranks full, and that work cannot be done in the laboratory only, working with test-tubes and microscopes ; it can be done by keeping in touch with the man in the ranks, and no appliance, mechanical or scientific, can replace that touch.

In peace-time there are two men in particular that the medical officer should keep his eye on. These are the aspiring young non-commissioned officer, and the regimental athlete. I remember more than one fatal case of enteric fever where the patient was a young lance-corporal or lance-sergeant, who kept away from treatment till too late, on account of that extra stripe he was so afraid to lose. On the other hand, the first case in one of the worst epidemics I was concerned with occurred in the champion football forward of his battalion, who died late in the third week of an attack. The actual cause of his reporting sick was a severe contusion in the buttock, which became gangrenous, the result of a kick received in a match played when the disease must have reached its tenth day or thereabouts.

Second to be considered of the three links of the chain concerned in the spread of a disease is the disease germ. This, as I have said in the opening definition, must have the power of passing from the infected to the healthy man directly or indirectly. It passes directly when it does not utilize the agency of an intermediate host, indirectly when it is carried by such a host—*e.g.*, the mosquito in malaria, or the glossina in sleeping sickness. The direct passage postulates one condition, and that is that the germ shall be able to maintain its existence during the period throughout which that passage lasts. It is of importance, then, to ascertain for how long the disease germ can retain its vitality and virulence outside the human body. The amount of experimental work which has been done on this point is enormous, and it is hardly an exaggeration to say that the

results have been almost as varied as the researchers. Certainly so far no absolute facts have been arrived at. It is impossible, for instance, for us to state definitely that any particular germ can certainly live so many days and can certainly not live so many more days, outside the human body. At the same time the balance of evidence appears to me to go to prove that the period is short; in other words, that the natural habitat of a human disease germ is the human body, and that the duration of its life outside the body depends largely on the extent to which the conditions to which it is normally accustomed inside the body are there reproduced. As a basis for practical sanitation, I feel justified in holding: (1) That when infective material leaves the body of an infected man it is dangerous, (2) that the danger is greatest at the moment at which it leaves the body, and (3) that it gradually diminishes as time elapses. Obviously, therefore, dealing with any potentially infectious material which we cannot destroy, the first thing to be done is to remove it as far as possible from the neighbourhood of the healthy man, or, if this is impossible, so to hide or cover it up that the egress of germs shall be mechanically prevented. The immediate danger is thereby guarded against, and we have time to think about how we shall deal with the more remote. It is on these grounds that I consider that the immediate removal of waste matters is so much more important than their ultimate disposal, and the immediate burial of excreta the keystone of camp sanitation. Taking the last case as an illustration, I am quite prepared to admit that where infective stools have been buried in a shallow latrine trench, it is possible that the specific germ may be brought to the surface at some later date, in a worm casting or by other such means. Personally, I think such danger is remote, but I would be the last to deny its possibility. The real danger, however, is present in the interval that elapses between the time that the germ leaves the body and the moment at which it is covered over with dry earth. The germ is never more virulent than it is at that moment, and the purely mechanical obstruction of the earth covering is sufficient to guard against the danger when it is at its greatest. It may be necessary to take more active steps later, as by burning litter on the surface of

the covered-in trench, etc., but it would be a fatal error to neglect the immediate covering-up with earth, because the more stringent measure was going to be carried out some hours afterwards.

Closely connected with the vitality of the disease germ outside the body is the question of its immutability. The generally accepted theory at the present moment is that a disease germ is a specific entity, and retains its specific pathogenic properties as long as it retains its vitality. Every fresh case of an infectious disease can, on this theory, be traceable back to a previous case of the same disease. To put a concrete case, if A suffers from enteric fever, he does so because he has ingested a sufficient number of enteric germs, which, in the last instance, came from B, suffering also from enteric fever, the descent of the germs which infected A being in an unbroken line from those which infected B. This is undoubtedly the accepted and orthodox view at the present day, but a certain number of bacteriologists have always held that the theory was not absolutely proven, and that disease germs could lose, and, again, in the process of generations, reacquire, their pathogenic properties. To return to the concrete case above, according to this view it would be quite possible that the bacilli which infected A were descended from certain harmless members of the same group, probably the *Bacillus coli*, which, again, might, or might not, be descendants of the virulent enteric bacilli, which originally infected B. My own working hypothesis is as follows : We know that the *B. typhosus*, if grown on suitable artificial media outside the body, may lose some of its typical cultural reactions, in particular that of the power of fermenting certain sugars. The work of Horrocks has also shown that by passage through experimental animals it may develop into an organism bearing little, if any, resemblance, morphological, cultural, or otherwise to the original stock. We also know that disease germs, if grown for a prolonged period on certain artificial media, do lose their virulence, which they can again acquire by passage through selected animals. There is, however, no evidence, as far as I know, that any germ which has so degenerated can recover its virulence so long as it is grown on artificial media only.

I accept, therefore, the possibility that the *B. typhosus* which leaves the body of B, can, during its life in the earth of a latrine trench, develop either into a typical *B. coli*, or into some organism so closely resembling the latter that the distinction is beyond the powers of any but an expert. I do not believe that so long as this degenerated *B. typhosus* remains in the soil it can recover its pathogenic properties, though possibly by repeated passage through human bodies it might, in process of time, do so. In any case, it is fairly certain that the longer the period during which it has been buried, the longer the process necessary for the recovery of its virulence.

If, as up till lately was the common belief, the only dangerous person was the patient suffering from a typical attack of the disease, and if his dejecta only, as, for instance, in the case of enteric fever, were to be considered dangerous, then undoubtedly the possibility that the common *B. coli communis* from a perfectly healthy man's intestine might develop suddenly, and assume specific pathogenic properties, would be decidedly disturbing. But we know now that the typical case, and even the carrier which develops from the typical case, are the least dangerous of all. The men we have to protect ourselves against are the concealed carrier, the ambulatory case, and the unrecognized and unrecognizable contact, and all evidence now goes to prove that in epidemic periods the number of these is enormous. In practice, therefore, we have to protect ourselves, not against fouling of our food and water with the excreta of the known cases of disease, but with those of the unknown ambulatory case and the unrecognized contact—in brief, all excreta.

In practice, especially as regards this particular disease, the distinction is not of enormous importance. If water has, to my certain knowledge, been recently polluted by human excreta, or if I have good bacteriological and chemical evidence that this has probably occurred, no amount of negative evidence pointing out the absence of enteric bacilli in that water would lead me to accept it as pure. On the other hand, if the pollution is demonstrably old, and slight in amount, experience shows that the water can be consumed with impunity, whether because all the specific germs have died out, or so far lost their specific characters

as to have become harmless, except, perhaps, to very exceptionally susceptible people, under very exceptional circumstances. It would be unwise for the practical sanitarian to take up too uncompromising an attitude on this subject of variability. It is distinctly one for expert bacteriologists to settle. Whichever theory is correct, there is no doubt in my mind that the really dangerous moment is that at which the disease germ leaves the body of the infected man, and that therefore our attack on the germ must be made then.

As regards the third link in the chain—the non-infected man—there is little to be said. I should like to emphasize one point, however. In the same way as it is necessary to distinguish between the "infected" man and the "diseased" man, so it is necessary to discriminate between the "non-infected" man and the "healthy" man. Theoretically, a "healthy" man should be impervious to the attacks of disease germs, and though this may appear to be, and probably is, an impossible ideal, still there is no doubt that the nearer a man approaches to the condition of perfect health the less liable will he individually be to suffer from the attacks of infectious disease. The first step in the prevention of infectious disease is, therefore, the maintenance of health—a point to which I have already sufficiently referred.

The innate powers of resistance possessed by the healthy man may be artificially increased by what is generally termed "vaccination." This process is, of course, best known in connection with smallpox; but of late years it has been extended to other diseases, most notably, as regards the army, in connection with enteric fever. In this process a killed culture of the *B. typhosus* is injected into the body of the susceptible individual, with the aim, and also with the undoubted result, of raising his powers of resistance to the micro-organism in question.

I do not intend here to go into the question of immunity, or discuss the theories on which the above method of artificially increasing that property is founded. As a practical measure, I consider antityphoid inoculation one of the greatest advances made of late years with regard to the prevention of that particular disease. It is necessary, how-

ever, to point out that it is only with regard to that particular disease, and no other. Inoculation can, therefore, be looked on merely as an adjunct to any general system of disease prevention, and not in any way as a substitute for those more widely-reaching measures which strike at the general causes of disease. This caution is necessary, since both administrations and individuals are apt to be fascinated by what appears to them a royal road to the prevention of disease, and neglect the more laborious and commonplace drudgery, without which no true sanitation can be effected. Scientific sanitation should aim at defending the individual as a unit of the community, not at defending the community by protecting each individual unit of which it is composed. We should therefore aim at preventing infectious disease by destroying disease germs outside the body, using inoculation only to protect us against those which may escape our efforts.

The prevention of disease, then, consists in preventing the passage of the micro-organism from the infected to the non-infected man. This we may do at one of three points on that passage—namely, (1) at the time when it leaves the infected man, (2) immediately before it enters the non-infected man, or (3) at some intermediate point. We have, therefore, in the case of any particular disease, to consider (1) how the micro-organism leaves the infected man, (2) how it enters the non-infected man, and (3) the media in which it lives during, or by means of which it effects, its passage from the one individual to the other.

Disease germs leave the body of the infected man in one of four ways—namely, (1) by means of the excreta (that is, the urine or fæces) ; (2) by means of the sputum ; (3) by means of particles of infected skin ; or (4) by means of the blood, through the agency of a blood-sucking insect.

Disease germs enter the body of the non-infected man also in one of four ways—namely, (1) by means of some article of food or drink ; (2) by inhalation ; (3) by actual contact of infective material with the unbroken, or more frequently the broken, skin ; or (4) by means of the bite of a blood-sucking insect.

It will be seen that there is a certain analogy between the different methods by which the germs leave and enter the

body respectively, and this analogy is maintained in actual fact. Thus, germs which leave the infected body in the excreta usually effect an entry into the non-infected body by means of some article of food or drink. Those which are ejected in the sputum enter by inhalation, and those which are withdrawn from the body in the blood abstracted by some blood-sucking insect enter the non-infected man through the bite of the same insect. It is to be noted, however, that, except in this last case, the germ, after it has left the body, may pass the interval that elapses before it enters another body in any substance whatsoever—that is, in the earth, air, water, clothing, or in any form of foodstuff. I have already discussed the length of time that it can exist in such situations, and stated that I consider that it is in all probability short. Nevertheless, however short it may be, the enormous number of substances that can afford the germ shelter makes it almost impossible to direct our attack against it with any certainty during this period. We are in practice, therefore, driven to concentrate our attention on the moments at which the micro-organism actually either leaves or enters the body.

Here, indeed, the problem is simpler. Every disease germ has its own particular method of departure and entry, and in the case of any particular disease we can, therefore, concentrate our attention on certain definite points. Thus, for instance, tubercle bacilli leave the body in the enormous majority of cases by the expectoration, and enter the body by inhalation. Enteric bacilli leave in the urine or fæces and enter by means of some article of food or drink. It is worth noting, moreover, that in any particular case the vehicles in which the germ leaves the body are less numerous than those through which it obtains an entry. Enteric germs can enter the body in or on any one of the numerous articles of food or drink that a man consumes in the course of the day ; they can only leave in the fæces or the urine (I am not talking here of exceptional cases). Tubercle bacilli effect their exit at longer or shorter intervals in the sputa ; they may contrive an entry in any one of the fifteen inspirations that a man makes every minute of his life. In addition, the infected men are few in number compared with the non-infected. It follows, therefore, that we shall

find it an easier matter to attack the micro-organism at that point in its career when it is just leaving the infected man than to try and intercept it just before it achieves its entry into the non-infected man. In addition, it is at this moment that we are justified in assuming that it retains, in the greatest sense unaltered, its specific virulence.

Dealing, as in the army on service we so largely have to do, with the so-called intestinal diseases—enteric fever, dysentery, and cholera—it follows that we must concentrate our attention primarily and chiefly on the disposal of excreta, which I have no hesitation in repeating, even *ad nauseam* of my readers, forms the keystone of all sanitation in war.

Passing from the general question, I propose now to discuss those infectious diseases which are of primary importance in military sanitation.

Enteric Fever.—Of these, the most important at the present day is undoubtedly enteric fever. In peace-time this disease is of rare occurrence in the army at home. The average admission-rate per 1,000 in the quinquennium 1905-1909 was 0·6, representing a total number of only 347 cases in the five years. In the Mediterranean stations it is comparatively rare, and, in fact, we may say that it is only in India and South Africa that it assumes important proportions. The large size of the garrison in the former station renders it of paramount importance, and in the following discussion I shall practically limit my references to the disease as we have to deal with it in that country.

At the outset I should like to touch shortly on the history of enteric fever in India, since a consideration of the disease from a purely epidemiological point of view throws considerable light on its causation. In conducting any investigation into the history of enteric fever we are, however, at once confronted by the difficulty of nomenclature. The statistics which are at our disposal go back to 1860, but, unfortunately, the expression "enteric fever," as used by army medical officers in the sixties, seventies, and eighties of last century, does not bear by any means the same significance as it does at the present day in the mouths of their successors. There is not the slightest doubt that many cases which are

now returned as enteric fever would, on account of the obscurity of the clinical symptoms, have in that earlier period which I have referred to been returned as remittent fever, ague, febricula, or simple continued fever. A few cases, possibly, in which the febrile symptoms were less prominent than those referable to the intestinal system, especially those in which hæmorrhage occurred at an early stage, may have been shown as dysentery. These, however, were not probably many in number.

If we take the period between 1860 and the present day, and class together all febrile diseases (excluding the exanthemata, which, fortunately, have always been rare), we shall be certain of including practically all the cases of true enteric fever in the numbers furnished. In the appended chart, I have constructed a curve (adapted from one originally drawn out for the Army Medical Department Report of 1906) showing the admissions per 1,000 of strength, and the deaths per cent. of cases treated, for this combined class of " all fevers " from 1860 onwards. It will be noticed at once that between 1860 and 1885 the death-rate per cent. of cases treated remained fairly steady between 0·5 and 0·9, never reaching as high as 1. After 1879, the year of the Afghan War, the admission-rate fell steadily, but, on the other hand, the case mortality showed a persistent rise, culminating at the end of last century. Since then there has been a fall, at first slow and not regular, but latterly rapid and continuous. It will be noted that whereas between 1860 and 1885 the case mortality never attained to 1 per cent., between 1886 and 1907 it never fell below that figure. During the latter period this ratio was on three occasions higher than 2 and on thirteen as much as 1·5 or higher. In 1908 the death-rate for " all fevers " was 0·9—a higher figure than was ever noted prior to 1886, whilst in 1909 it was still as high as 0·7, pointing to a mortality higher than that noted in seventeen out of the twenty-six years between 1860 and 1885. In 1910, for the first time since 1876, the " fever " death-rate for our troops in India fell to below 0·5. The contrast shown on the table below between the admission and death rates for the years corresponding to the Afghan War (1879-1880), and those for 1897 and 1898, the years of the Tirah Expedition, and the concentration

CHART SHOWING ADMISSIONS PER 1,000 OF STR
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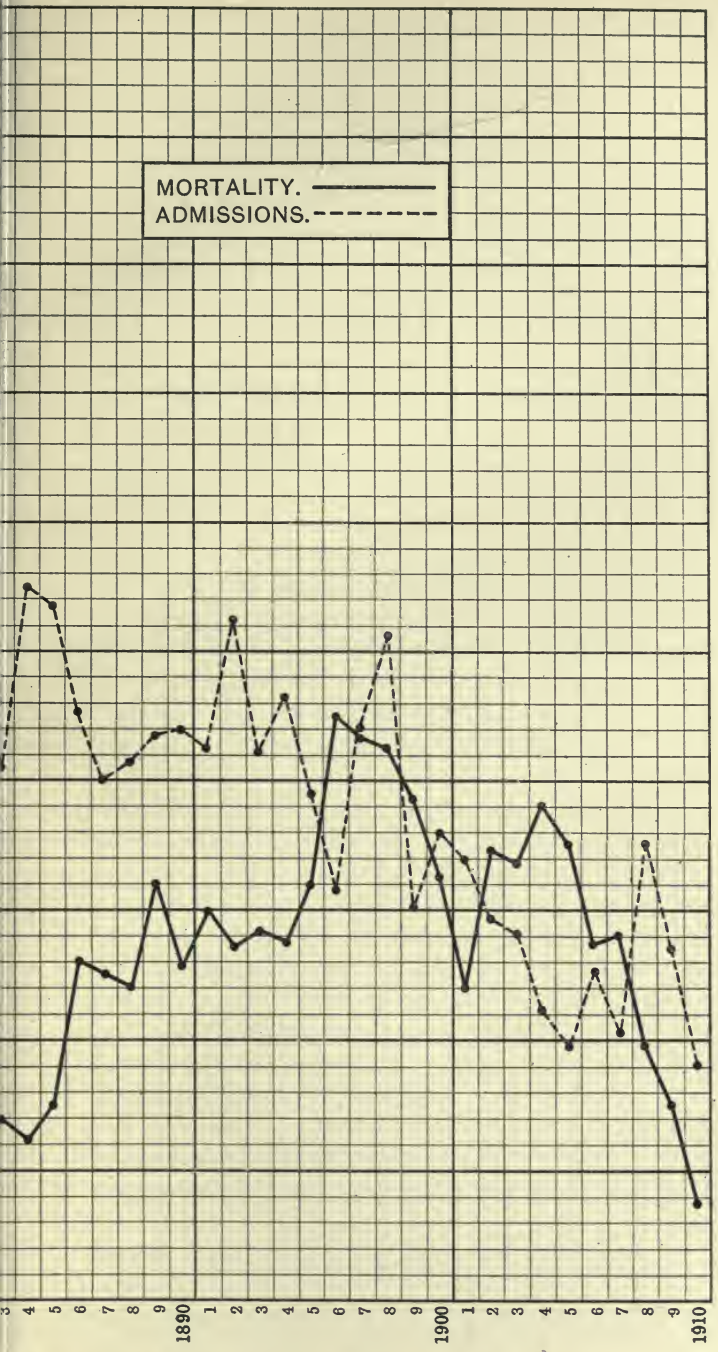


GTH AND CASE MORTALITY PER CENT. FOR "ALL FEVERS"
DIA, 1860–1910.

[*To face page* 342.

of troops on the frontier that followed that campaign, is peculiarly interesting :

RATIOS FOR "ALL FEVERS" DURING TWO CONTRASTED PERIODS.

	Admitted per 1,000 of Strength.	Died per 1,000 of Strength.	Case Mortality per Cent.
1878	635	5·2	0·82
1879	940	5·1	0·54
1880	790	5·4	0·68
Average	—	—	0·68
1897	440	9·4	2·14
1898	515	10·8	2·10
Average	—	—	2·12

To my mind the conclusion is fairly clear that the "fevers" with which we have had to deal in the last twenty-five years are different in nature from those with the treatment and prevention of which our predecessors were concerned in the quarter of a century immediately preceding. If we were dealing with one disease only we should be justified in saying either that the disease had become much less amenable to treatment, or the population more susceptible to the disease. Dealing with a mixed class of diseases, linked together only by one common symptom, pyrexia, we are, I think, justified in concluding that the more severe members of the group have increased, whilst the less fatal have diminished or remained stationary. Now, there is not the slightest doubt that the fatal fever of India, as regards the British soldier, is enteric fever. The deaths attributable to malarial fevers, or to simple continued fevers, are negligible in comparison.

I conclude, therefore, that the fatal member of the combined group—in other words, enteric fever—was undoubtedly more prevalent in the years between 1886 and 1910, than it had been in the years prior to 1886, as far back as our statistics go. The change occurred subsequently to the second Afghan War, and may be supposed to have commenced somewhere between 1883 and 1885, though it did not show itself prominently till 1886. This change coincides with

the final passing away of the long-service soldier, and the introduction of the present shorter period of service. It also coincides rather interestingly with the period of the Egyptian campaigns lasting from that of Tel-el-Kebir, in 1882, to that of the Nile Expedition in 1885. It is at least conceivable that the troops coming on to India after sharing in those campaigns introduced it into the latter country, or, rather — for it has always, I believe, been to a certain extent present — increased the number of foci from which it subsequently spread. The culminating point of enteric fever was in the years 1897 and 1898. In the former we had the great concentration of troops in the north of the Punjab, in connection with the Tirah Campaign, and in the latter the occupation of the Khyber Pass, coinciding with two appalling outbreaks at Agra and Quetta. In 1899 there was a marked fall, partly, perhaps, due to the protection afforded by the numerous attacks of the preceding years, but partly also to the fact that the outbreak of the South African War put an end to the arrival of young drafts from England. This last influence persisted during the next two years,

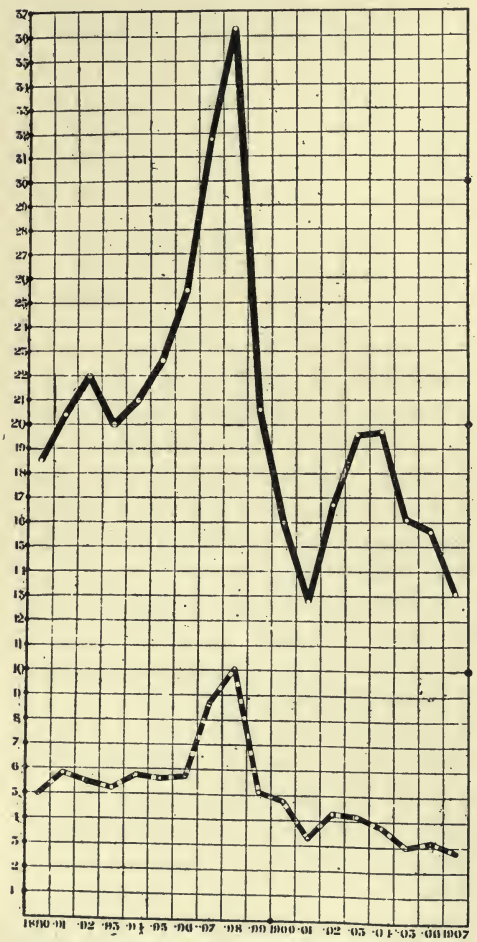


FIG. 9.—ADMISSIONS AND DEATHS PER 1,000, ENTERIC FEVER IN INDIA.

which also coincided with a marked improvement in sanitary administration in India. The appointment of sanitary officers at the headquarters of the army, and at the headquarters of the four commands, had a most important effect in consolidating and co-ordinating sanitary work throughout the army. It is to this, and also to the introduction of anti-enteric inoculation, that I attribute the present improved state of affairs. As regards this last measure, I consider that the history of enteric fever in India is of very great significance. I believe, as I have already said, that one of the most important causes of the great prevalence of enteric fever during the closing fifteen years of last century was the presence of the great mass of highly susceptible material in the country, represented in the persons of the young soldiers of which the army was composed. This increased susceptibility, due to age, should logically be combated by an artificially increased power of resistance, and this power is furnished by inoculation, and can be furnished to the same extent in no other way.

There is one more point in connection with the history of enteric fever which seems to me to point a valuable lesson. As all who served in India during that period know, the years 1880 to 1900 were years marked by continuous improvement in the matter of water-supply. (I will refer to this again when discussing cholera.) New piped supplies were introduced into many stations, and, where this was not done, great and continually increasing attention was paid to the details of water-supply in barracks throughout the country. This was even more marked in the years after 1895, in consequence, partly, of the fact that some weak points in the systems then in force were brought to light by the cholera outbreak at Lucknow in that year.

During just those years when enteric fever was at its worst, and seemed every year to be getting more out of control, the energies of every medical officer were being daily, almost hourly, directed to safeguarding the water-supply. By some irony of fate those stations where the water-supply was best seemed to be those specially selected by this disease to deal its hardest blow. In no case was this more marked than at Quetta. The water-supply in this station was, and is, drawn from a mountain source, as

free from danger of serious contamination as any source could well be. It was piped for about fifteen miles to a service reservoir, placed as far as possible from any obvious source of danger, and thence delivered to stand-pipes in the barracks. If any contamination had occurred at the source, or in the service reservoirs, the resulting outbreak should have been general in its character, and marked by the well-known features that distinguish such outbreaks. If, on the other hand, contamination had occurred during distribution from the stand-pipes, then this would have been local, and given rise to localized outbursts, following no general rule, in different years. As a matter of fact, however, the outbreaks were general in their character, and year after year showed a very definite resemblance. Thus they always began at a certain part of the infantry lines, were always worst in that part and the immediate vicinity, and spread from thence to the remainder of the station. The spot from which they started was that nearest to, and directly to leeward of, the filth trenches, and the direction in which the epidemics spread was always down the wind. Owing to lack of water, and the nature of the soil, the trenches were absolutely arid, and the miniature whirlwinds or sand-spouts, well termed "devils" by the natives of the country, swept straight from these trenches into the lines, carrying clouds of dust and swarms of flies with them. The inference, to my mind, at the time, was clear, and I have never yet seen any reason to doubt it—namely, that the dust and flies carried into the barracks originated, and assisted in the subsequent spread of, enteric fever in the station. The trenches were closed, and deep pits dug at a place somewhat nearer to barracks than the point where the trenches were previously situated, but in a direction from which the wind rarely or never blew. At the same time certain improvements were instituted in the system of removal then in force, with the result that admissions for enteric fever, which in 1898 were 232, in 1899 were only 26, though the garrison remained at the same strength, and a new battalion was substituted for one that had been protected to a certain extent by the previous severe outbreak. I occupied at the time the position of sanitary officer at Quetta, and was in a favourable position to study

the local conditions. This experience, coming as it did at the close of my second tour of Indian service, confirmed in my mind conclusions to which my experience of twelve years in that country had been progressively leading me. During those years enteric fever had been steadily increasing in India, and I had had the fortune to be brought into close touch with many outbreaks, none of which showed any of the features that characterize a purely water-borne epidemic. The conclusion to which I came was that flies and dust, combined with faulty methods of removal and disposal, were the chief causes of enteric fever in Indian cantonments. A further experience of four years as sanitary officer, first at the headquarters of a command, and later at those of the army, did nothing to lessen, but the rather strengthened, my conclusions. Water can, and does doubtless, cause sporadic cases, and even isolated and circumscribed outbreaks ; it is not, I hold most strongly, concerned in the continuation of epidemics such as those with which the eighties and nineties of last century made us who then served in India so familiar.

Enteric Fever in Cantonments.—In considering the prevention of enteric fever in cantonments we must begin with the infected man. Of the man actually under treatment in hospital, little need be said. The dejecta of all cases of enteric fever will naturally be received into a bed-pan containing disinfectant, and they should after that be either incinerated or boiled. The latter process should, in my opinion, always be selected, since, in carrying it out, the bed-pan can, at the same time, be sterilized. It is occasionally forgotten that the washings of a bed-pan are as dangerous as the actual excreta. Reliance should never be placed on mere chemical disinfection, whether for excreta or utensils. Even in the smallest hospital it should be possible to fit up a large caldron in the immediate vicinity of the ward, which should be kept full of water, to which a certain amount of washing soda has been added. In this the bed-pan with its contents should be immersed. With several cases it may be necessary to keep the caldron always simmering, in which case the bed-pan need not be left in the water more than a few minutes. The soda will assist to saponify any fatty matter that may be present, and cleanse the pan.

Where only a single case is in question, the water must be brought to the boil and maintained at that temperature for two or three minutes. If the bulk of water be large compared with the stool, there will be no nuisance ; if such be complained of, the addition of sanitas or crude carbolic acid to the water will counteract it. In large hospitals some more elaborate apparatus should be supplied with a view to economizing fuel and labour, but it is a mistake to suppose that elaborate apparatus is necessary. The stools of all doubtful cases of fever should be treated in the same way.

The infected man out of hospital may belong to any of the four categories already described. The actual " carrier " is nowadays easily recognized and isolated, and the danger from him should be infinitesimal. Since every man who has had enteric fever is examined on several occasions to ascertain if he is a " carrier " or not, it is probable that but few escape the net. In case, however, any such should elude our vigilance, I lay down as a hard-and-fast rule that no man should be allowed to handle the food of his comrades for one year after he has returned to duty subsequently to an attack of enteric fever. He must, therefore, not be employed in the kitchen, regimental dairy, soda-water factory, or coffee shop, or on any duty which would entail his handling food during that period. At the end of it, if it is desired so to employ him, he should be again examined on, say, three separate occasions, with a week's interval between each, to see whether or no he is a " carrier." In the case of men who have returned to duty after being orderlies in an enteric ward, I should make a similar rule, but limit the period to six months. I do not pretend for one instant that there is any particular virtue in, or any scientific justification for, the periods I have stated. In such a case I decline to take risks, and, as a matter of administration, it is always a sound step to lay down some definite rule. The instances in which any hardship would be inflicted would be extremely few, and the hardship very small in any of them.

Dealing with the case in the early stage of the disease, and with the ambulatory case is a difficult matter. In nine cases out of ten, however, in typical attacks, men report sick about the fourth day of disease : the danger here is

therefore limited. I have already spoken of the two men whom it is the duty of the medical officer in charge of a unit specially to keep his eye on—the keen young N.C.O. and the regimental athlete.

In respect of enteric fever there is one other class of individuals demanding particular notice, and that is the member of the last draft. Every medical officer in charge of a unit should make it his duty to see, and by that word I mean not merely look at, but speak to, and question, the men who composed the last draft from home, periodically, at frequent intervals during the first six months of their Indian service. These men are not only the most susceptible, on physical grounds, but they also suffer from ignorance of the country, and of the dangers of the bazaar. Undoubtedly some of them contract the infection on their journey up country. One such case which I remember was the starting-point of a rather important outbreak. He had no pronounced symptoms, and was not recognized until a thorough overhaul of the "last draft" was made, when it was discovered that he had been suffering from malaise and intestinal trouble ever since his arrival in the station, and acting as a focus of the disease all that time, more than six weeks. Detached parties of men coming from another station, where enteric fever has been prevalent, should also be carefully watched, to prevent their introducing the disease into a station which has been previously free from it. This is particularly likely to occur in the case of stations where special courses of instruction—for instance, signalling, musketry, and mounted infantry classes—are carried out.

The next point to be considered is the direct attack on the disease germ. From what I have already said, I think I have made it fairly clear that this attack must be made at the moment when the germ leaves the body of the infected man. And, since we are dealing with the infected man outside hospital, that means that we must concentrate our attention on the latrines and urinals in barracks. I have already dealt with the question of the removal and disposal of excreta in the absence of a water-carriage system, and it is unnecessary to repeat what I have already said on that matter. In my opinion the conservancy problem is the key of the enteric problem in India. The method which

I consider the best is incineration *in situ*, with the most stringent precautions to prevent the access of flies to the excreta during the interval that must inevitably elapse between the moment when they leave the body and their ultimate destruction. Where incineration *in situ* is impossible, then the precautions as regards flies must be extended to the entire period during which the excreta are retained in the latrines, and also during their transfer to the disposal-ground. I firmly believe that if there are no flies in barracks there will be no epidemics of enteric fever. Isolated cases contracted in the bazaar may occur, occasionally even a small outbreak of the water type. In the absence of flies the disease will not "get hold" of the station, and you will not have the type of outbreak with which all those who served in India during the nineties of last century are so well acquainted, persisting, week after week, and month after month, one year with another, sometimes more severe, and sometimes less, but never absent from the station.

As regards the passage of the germ from the infected man to the non-infected man, the fly is, therefore, the object of our attack. Flies must not only be kept out of latrines; they must not be allowed to breed anywhere in the vicinity of barracks. Here we are concerned with the destruction of rubbish, more especially with that of horse-litter. Mounted units naturally are the most important in this connection. Apart from the fly, there is one other agent that must not be forgotten, and that is the low-caste native servant. Fortunately, of late years the number of these allowed in barracks has been considerably diminished, and with that much-to-be-desired consummation, the introduction of electric fans or punkahs, it may be hoped that they will almost completely disappear. There is, in fact, not the slightest reason why any native should ever enter a barrack-room or ever manipulate food. Cleaning-boys and parasites of that class should be absolutely forbidden. The number of natives allowed to enter barracks, as apart from barrack-rooms, should be strictly limited, and everyone so authorized should either wear some sort of uniform or a conspicuous badge.

With regard to the non-infected man, our defence must consist in protection of his food and water supplies. With

regard to the former, we have to think firstly of the kitchen. It is becoming more and more the practice in India for the soldier to do his own cooking. With the introduction of proper cooking-ranges this is possible in some stations all the year round, and in a great number of the larger stations for considerable periods of the year. Where and when it is impossible, the rôle of the native cook should be that of a fire-boy. He should on no account be allowed to manipulate the meat or prepare it for cooking. This can and should always be done by a trained soldier cook. As regards kitchens, we have again to think of the ubiquitous fly. There should be no flies in kitchens, and the only way to insure this is by having no breeding-grounds in or near barracks. One cannot in this case use strong-smelling chemicals to drive out the fly, as in the case of latrines. Wire gauze doors are provided in all cook-houses, and are always shut on the occasion of the arrival of an inspecting officer, if this is known of in advance. I am with good grounds sceptical of their being closed at any other time, except by accident. It has always seemed to me that the old-fashioned split bamboo curtain, or chick, was more efficacious than the modern automatic closing door. In either case, I have little faith in any automatic appliances. The only way to insure the absence of flies in cook-houses is to see that there are no breeding-grounds in or near barracks. The prompt removal and disposal of cook-house rubbish and slops is, of course, important in this connection.

The soldier's food is derived from three sources. The first is the supply branch of the Supply and Transport Corps, which provides the main articles composing the regulation ration ; the second comprises the various regimental institutes—viz., coffee-shop, supper-bar, and dairy, etc. ; and the third includes various extraneous sources, native and European.

As regards the official supplies, little fault can as a rule be found, and, if found, can at once be remedied. As regards the second, there is as a rule, except in an absolutely raw regiment, little amiss. If there is trouble, it is uually in connection with the dairy, and consists in the fact that the supply of milk from the regimental herd has fallen short, and has had to be supplemented from ex-

traneous sources. In nine cases out of ten regimental dairies are under-capitalized, and have no reserve of stock. The difficulty lies in the fact that a regimental dairy has, or should have, no market outside the regiment. It must, therefore, either produce more milk than it needs for its own customers, or some of these must occasionally go short. Rarely one sees a good regimental dairy, still more rarely a good one which limits its market to the regiment only. The milk-supply of the garrison should either be from a Government dairy, or, better still, from a large civilian dairy under skilled European management. Any licence to sell milk in barracks should be conditional on the dairy being open to inspection by military medical and veterinary officers. The amount of milk consumed by the ordinary soldier is so small—about 1½ ounces per diem—that I am, I confess, sceptical as to its influence as a cause of enteric fever. The women and children who do drink milk do not suffer from the disease to anything like the same extent.

Supplies from extraneous sources consist largely of fruit and vegetables sold by native hawkers. Every unit should establish a central market for the sale of these commodities. No native should be allowed to hawk foodstuffs of any description whatever promiscuously through barracks. Some convenient spot should be selected, and the fruit, etc., exposed for sale on clean tables or stands properly protected from dust and flies. A plentiful supply of good fruit and green food is an absolute necessity in a hot climate, and if the men are not given this in barracks they will inevitably procure it in the bazaar. Soldiers' gardens should be encouraged with this view, but they rarely, if ever, produce enough to meet the demand. Every native hawker should be provided with a conspicuous badge, and also a signed pass, supplied by the Quartermaster.

An extraneous source of supply which occasionally gives trouble is the unauthorized Soldiers' Home. The large Soldiers' Homes established at many stations under the management of responsible persons have been productive of great good, and of nothing but good, and it is not these that I here allude to. In addition to these, in various stations smaller so-called homes have been started, often of a sectarian character, as a rule inadequately financed,

being, in fact, nothing more than restaurants of a poor class. In my experience these are more common in the south of India than in the north. Such establishments should be placed out of bounds unless they submit to inspection by military medical authorities, and abide by certain rules. Inside cantonment limits effective control is simple enough, but where a municipal form of government exists, unless some sort of fixed rule like the above is enforced, trouble will undoubtedly ensue.

I have already given my reasons for believing that water-supplies do not play, and have not as a rule played, an important part in the production of enteric fever in India. That on occasion water outbreaks do occur I am well aware, and naturally attention should be paid to the water in investigating or combating any epidemic. The ideal water-supply in India would be one in which the water was laid on to every barrack-room, so that the man should be able to fill his own bottle or mug straight from the main. In the majority of stations this is not the case, and some method of storage in the veranda has to be adopted. Great harm has been done in India by over-meddling with the water-supply. Where a water is originally drawn from a good source, and delivered to barracks in stand-pipes, the chances of contamination *en route* to the barracks being guarded against as far as is humanly possible, then the less that water is handled on its passage from the stand-pipe to the consumer the better. I have already touched on these points when talking of water-supply, and merely recall the principle here.

Prevention of Enteric Fever on Service.—The prevention of this disease in the field must proceed on exactly the same lines as in cantonments. We must consider the same chain of individuals, and attempt to break up that chain in precisely the same manner. The first object of our attention, then, must be the infected man, and from that it follows that our first line of defence must be the care of latrines and urinals. I am not so optimistic as to expect that even with the best disciplined and the most highly educated army we shall ever escape the dangers incidental to promiscuous defæcation and urination, more especially the latter. But this may be reduced to a minimum, and must be reduced.

With soldiers, the difficulty will not be nearly so great as with civilian camp-followers, especially natives. The most stringent disciplinary measures may be necessary in the case of these gentry. I need hardly repeat here the importance of the destruction of all rubbish, so as to discourage the breeding of flies.

Whatever you do, and however hard you work, you will still have a certain amount of scattered filth and a considerable number of flies. I want to warn young officers from getting into that mental attitude which leads to a passive acquiescence in this state of affairs. The next stage is the "What is the good of anything?" stage, and that is fatal. Half a loaf is much better than no bread in this case, and he is the best sanitary officer who makes that half into as big a fraction of the entire loaf of perfect sanitation as he can.

The same remarks apply to water-supply, though here it is much easier to approach perfection, since the supervision of the collection and distribution of water is a simpler matter than that of the prevention of promiscuous defæcation. Here, again, however, I do not lay as much stress on water-supply as on conservancy in the causation of enteric fever in the field. Exposed excreta and flies are the main causes of the disease. Our defence against these must necessarily be imperfect, from causes which, if not beyond human control, are sometimes very nearly so. I conclude, therefore, that the main line of defence must be to increase the resisting-powers of the non-infected man—in other words, the practice of anti-enteric inoculation. This is the logical method of counteracting the increased susceptibility of the young soldier, of whom all modern armies are so largely composed. I hold, in fact, that a battalion or other unit must, as far as enteric fever goes, be considered as being fit for service in exact proportion to the number of protected men in the ranks.

Dysentery.—This disease has in the past played an important part in the medical history of the British Army both in peace and war. At present, except in a few small stations, its influence in peace-time is negligible, whether considered as a cause of sickness or of mortality. In India, for instance, during the year 1909 the admission-rate was

11·2 and the death-rate 0·25 per 1,000, the averages for the quinquennium immediately preceding being 13·4 and 0·44 respectively. In the older days this was not the case. Certain stations, and even certain barracks—as, for instance, the old European infantry barracks in Secunderabad—had a peculiarly evil reputation for dysentery. In South Africa it caused a considerable amount of disability, and some mortality, but was in no way comparable with the disease as we read of it in history—as, for instance, in the earlier period of revolutionary wars in France. In the Middle Ages dysentery appears to have occupied, as regards campaigns, very much the position which enteric fever occupies at the present day. In all probability scurvy played a large part in its production in those times, aggravated by the alternate starvation and excess which regulated the commissariat of mediæval armies. The descriptions of the disease given by Donald Monro fortify this opinion.

Under the term "dysentery" are included at least two severe specific diseases, and in all probability a large number of minor complaints. The two former are bacillary dysentery and amœbic dysentery, each of which is due to a distinctive micro-organism. It is possible, however, that there may be more than one form of bacillary dysentery. In addition, we have included under this heading all the various forms of colitis or diarrhœa, marked by bloody stools, or by colic and tenesmus, which are usually shown under the same heading. Some of these are undoubtedly of a non-specific and temporary nature, due to chill, or the mechanical irritation produced by the presence of sand or grit in the water. Others, again, which are slight and temporary, may be related to or be quasi-ambulatory cases of the more typically severe forms.

As regards prevention, the question is comparatively simple, since there is no doubt that in the specific bacillary and amœbic dysenteries the infection leaves the infected man in his excreta, mainly, if not solely, in his fæces ; whilst in all cases it enters the man by the mouth in or on his water and food. The chain connecting the infected and the non-infected man is precisely similar to that existing in enteric fever or cholera, and the whole mechanism of prevention is, therefore, absolutely identical. It is unnecessary to repeat all

that has already been said about the strict attention to conservancy and water-supply that is necessary during service in the field. The possibility of a scorbutic factor existing must also be kept in mind and properly guarded against.

The three diseases—enteric fever, cholera, and dysentery—may from the point of view of prevention be considered as forming a circumscribed and well-marked group. In all, the mode of departure from the infected man is in the dejecta; in all, it enters the non-infected man in drink and food, and in all three the common fly provides a link between the two. Practically, therefore, though at any one time one or other member of the group may occupy our attention more than the other, the general lines on which we work are identical. In preventing one we prevent at the same time the other two. This statement does not, however, apply to methods of inoculation. Here we attack and

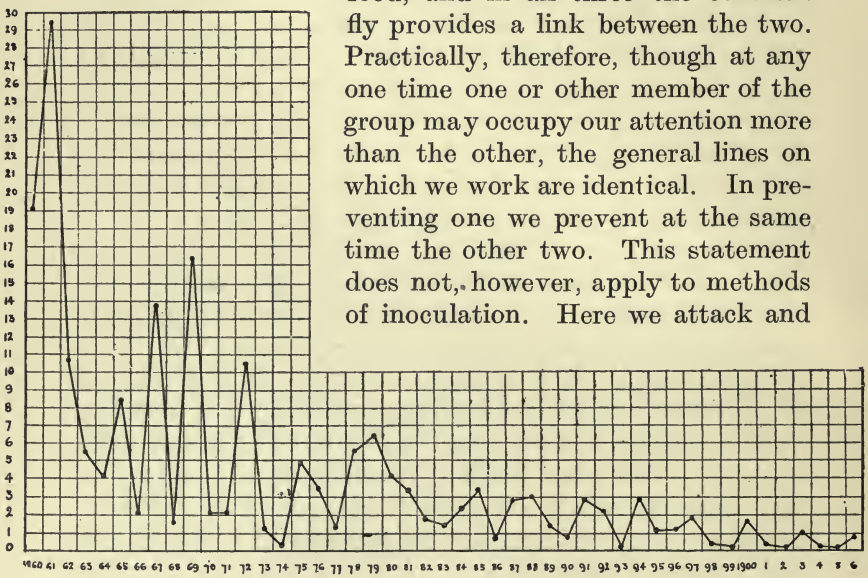


Fig. 10.—Cholera in India: Admissions per 1,000.

prevent only one disease, and though this is a great and useful help, it must not be supposed that it can in any way replace the more general methods of sanitation, conservancy, and water-supply.

Cholera.—This disease has practically never attacked the British Army in peace-time except in India, though occasional outbreaks have occurred under semi-service conditions in other countries, as well as in Turkey before the invasion of the Crimea, and in Egypt in 1883. The history of cholera, however, as far as we are concerned, is its history in India only, and will, therefore, be so considered.

The curves on Figs. 10 and 11 illustrate this history, showing the admissions and deaths per 1,000 of strength from the British Army in India since 1860 on account of this disease. The most striking point about these curves is their closeness to each other, emphasizing the enormous proportionate mortality that is distinctive of cholera.

If we divide the period covered by these curves into the different decades of which it is composed, we shall find that in the sixties cholera was always present, and that, roughly, every alternate year was marked by an appalling epidemic. In the seventies cholera was still constantly present, but the outbreaks were less severe and less numerous than before. In the eighties and nineties the disease gradually decreased till, at the present day, it is only of occasional occurrence. The change is, in reality, more marked than appears, especially in late years, from the curves. Twenty-five years ago, to go no farther

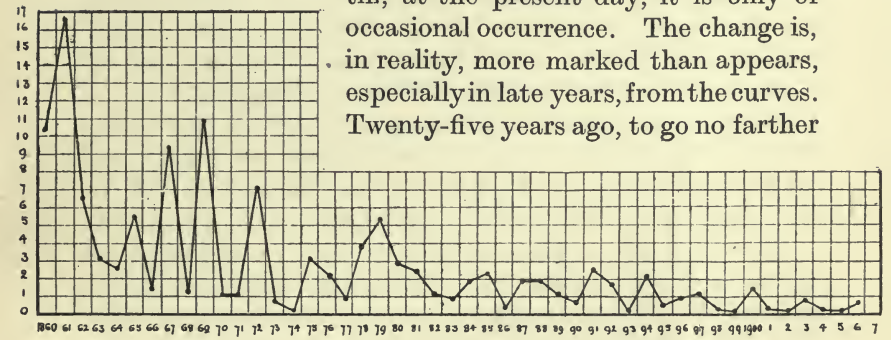


FIG. 11.—CHOLERA IN INDIA: DEATHS PER 1,000.

back, cholera was a constant visitant to all the up-country stations in India towards the end of the rainy season. The troops might escape, but the disease was always hovering round barracks as it were, and the medical authorities were constantly on the *qui vive* to meet attack. This is no longer the case. The disease, from being a great probability, has dwindled to a mere possibility. The explanation is, to my mind, clear, and I think there will be few dissentients amongst those who have studied the facts. Cholera has disappeared because water-supplies have improved, and for no other reason. The connection of water-supply with cholera was not generally recognized in the sixties. In the seventies the teachings of Parkes bore fruit, and during that decade and the next increasing attention was paid to water, as the essential nature of the connection

between it and the disease became more and more clearly recognized. The culminating-point was reached in 1894, when an outbreak in the East Lancashire Regiment at Lucknow demonstrated in the clearest possible manner that water, and water alone, was the vehicle by which the cholera vibrio was communicated to man. Since that time we have had no outbreak of serious importance. Sporadic cases have occurred, and probably always will occur as long as cholera continues to be endemic among the natives of certain parts of India. It should not, and it may be confidently prophesied will not again ever, in peace-time, appear in the form which it assumed in the sixties and seventies.

In war it is difficult to be equally optimistic. Even in our last frontier campaign, the Mohmand expedition of 1908, the disease appeared, and though limited in extent caused considerable trouble. Fortunately the campaign was not sufficiently long, nor the force employed sufficiently large, for much harm to be done. This might not always be the case, and with any large army keeping the field for a prolonged period close to any of the great Asian trade routes, it would be necessary to keep a very careful lookout for this disease.

Enteric fever is the standing menace of armies in all climates, but in tropical and subtropical countries cholera will still have to be reckoned with as a serious possibility. The difference between the two diseases in their relationship to military operations is rather important. An epidemic of enteric fever, however prolonged, would have an effect on the advance of an army similar to that produced by the "snipers" of an enterprising guerrilla foe. It might delay for a time, but would not eventually stop, the forward movement. The outbreak at Bloemfontein in 1900 is a good illustration of this. An outbreak of cholera, on the other hand, even if it lasted only ten days, might produce an effect comparable only to a crushing defeat by an overpowering enemy. Such an outbreak, for instance, as struck the army in the Khyber Pass on its return from Afghanistan in 1879, might, if it coincided with an important strategical concentration, alter the course of a campaign, and change the current of history. He would be, indeed, a bold man who would say that such an accident was impossible at the present day.

The prevention of cholera on service has, therefore, a strategical importance greater than that attached to the prevention of any other disease.

In studying the prevention of this disease, we have, of course, to consider the same chain as in all other infectious diseases.

As regards the infected man, we do not know so much as in the case of enteric fever The "carrier"—that is, the man who has passed through a typical attack of the disease and continues to discharge the vibrio in his stools—is probably less common in the case of cholera than in that of enteric fever, for the grim reason that the percentage of recoveries is less. The ambulatory case is possibly more common than generally supposed, and many of the cases of mild diarrhœa that occur during an epidemic are probably of this nature. The vibrio leaves the body only in the stools, at least, in the early stages of the disease, and it is to the immediate destruction of these that we must aim as the first step. On service on the Indian frontier, where the necessity is most likely to arise, this would entail the carriage of fuel, since nothing short of incineration would suffice. Again, though it might be possible to insure the incineration of all excreta passed in the case of the regular soldier, those of the inevitable crowd of transport and other followers would present enormous difficulties. A certain amount of illicit defæcation would occur, especially on the line of march, and this would be particularly likely to happen at the onset of symptoms of the disease. Still, attempts should be made to burn as much as possible, and the ubiquitous kerosene oil of the East should be utilized in the filth trenches for this purpose. In all standing camps or posts on the lines of communication, some permanent method of incineration should be adopted.

The vibrio of cholera is very sensitive to desiccation, and the danger of dust-borne infection is, I consider, less than in the case of enteric fever. Still, this method of dissemination, and also that by means of flies, should be kept in mind.

As regards the non-infected man, the prevention of cholera resolves itself into the provision of a pure water-supply. If cholera is present, or even threatening, the most minute and meticulous precautions must be taken in the matter

of water-supply, both as regards collection, purification, and distribution. In camp, whether during peace or war, the source should be guarded by an armed sentry, and there should be no ambiguity in his mind as to the reasons for which he is armed, nor should there be in the minds of others any room for imagining that he will not justify those reasons.

For purification I would trust nothing except heat, if it can be applied, and if the water can be satisfactorily cooled afterwards. This last would present great difficulties on service in the hot weather, with troops on the move. If heat is not available the next best method under the circumstances would be the use of chemicals. The acid sulphate of soda would undoubtedly be most useful in this case, and would probably be effective in doses considerably smaller than those usually recommended, owing to the extreme sensitiveness of the vibrio to acids. I have never yet seen the filter which I should trust in the actual presence of cholera.

I have already, when speaking of the general question of water-supply, stated what I consider should be the procedure adopted for collection and distribution. If formality and care are necessary under ordinary field service and manœuvre conditions, they are ten thousand times more important in the presence, or under the threat, of cholera. I need hardly add that it will be too late to insist on that formality and care, when the disease is already imminent. Practice and instruction in peace are as essential in the details of water discipline as in those of fire discipline. The commanding officer who expects his men to adopt suddenly, in the presence of disease, a rigorous self-restraint in the question of drinking without previous training in the art, is as likely to be disappointed as he who expects his men to husband their fire in action, when they have been allowed to squander it on manœuvres.

In cantonments, if cholera should appear, I would stop the issue of any water except that which had been boiled and aerated at the regimental soda-water factory. The cost of such a procedure would be infinitesimal, and the protection afforded complete. In hot weather I would go even further, and have the soda-water iced. I need hardly

say the ice should not be issued to the men, but used in chests, where the soda-water should be stored.

Personally, however, I still believe, archaic as it may seem, in the old precaution of moving into cholera camp. By so doing the connection between the troops and the actual source of the infection is cut, and, almost as important, the melancholy associations of the barrack-room are removed. In making this move it would be necessary to insure that no water vessel that had been used in barracks should accompany the unit under canvas, with the single exception of the individual water-bottles. These should all be sterilized by pouring in ½ ounce or 1 ounce of acid. sulph. dil., rinsing well round, and then emptying. This done, the man should be made to fill his bottle with still hot boiled water, and pending the cooling of this, he must not be allowed to drink anything but tea, or regimental aerated water. This sterilizing process must be carried out under the immediate supervision of an officer, preferably the company officer. It must on no account be left to the non-commissioned officers ; not in any way because these men are not to be trusted, but because the man in the ranks will estimate the importance of the procedure entirely by the rank of the individual superintending it. The bottles of all men who have been actually admitted to hospital should be burnt at once. It would probably be necessary to take out into camp certain large receptacles for the storage of water near the tents. Ordinarily these stand in the verandas of the barrack bungalows. If possible, new clean receptacles should be obtained from store to accompany the unit, but if this is impossible, those in use should, after being emptied, be disinfected, either by the use of acid, or more simply by laying a layer of paper and straw in the bottom of the receptacle and setting fire to it. This will not damage the tub, and will effectually destroy any lurking infection.

In camp water will probably have to be drawn from a well, and here all the precautions I have already mentioned should be observed, the armed sentry, the formal drawing and distributing of water by a special party, and so on. If the camp be near cantonments, say within twenty miles by road, free soda-water should be issued.

As regards other supplies, I should lay down at once that

none of any kind, sort, or description, should come into camp except those coming from official sources. No native hawker should be admitted into camp, and as few natives of any kind as possible. The consumption of fruit and vegetables should be carefully controlled. Such as are intended to be eaten raw must be limited to thick-skinned fruit that can be thoroughly scrubbed. It would be advisable to prohibit the use of salads, though these can be rendered practically safe if a good supply of vinegar is issued with them. All restrictions applied to the men in these respects should be made equally applicable to the officers' mess.

Naturally, particular care should be paid to conservancy ; the filth trenches should be covered with straw, or dry litter, and the latter burnt, at least once in the twenty-four hours, and preferably twice—namely, in the forenoon and at "retreat."

I should like to impress on any medical officer who may have to accompany troops into cholera camp, the necessity of paying particular and personal attention to all the details of sanitation all the time he is in camp. Generally speaking, meddlesome sanitation is a mistake and is apt to cause friction. But when an actual crisis occurs, such as an epidemic of cholera, the medical officer must take personal charge of the situation, and by so doing emphasize the importance of the sanitary precautions he insists on. He should himself see the water drawn, the trenches fired, etc. ; he must himself see all supplies brought into camp, and satisfy himself of their fitness. If the private soldier sees that the medical officer considers the special rules he has made are of sufficient importance for him to sacrifice his own comfort and leisure to insure their efficient observance, that astute individual will accord to those rules a respect which, in course of time, he will probably extend to their promulgator. If, on the other hand, he sees that the medical officer, having engineered a few more additions to the Regimental Order Book, considers his own recommendations of so little real value that their ultimate fate can safely be left to the quartermaster's establishment, he will label those rules "doctor's fads," and view them with a contempt which he will later inevitably extend to their author.

In connection with the prevention of cholera there is one line of action, the importance of which is not, I think, sufficiently recognized, and that is the advisability of being prepared in advance. When cholera does come, it is apt to come with but little warning, and after only short notice. This disease is peculiar, above all those with which we are commonly brought into contact, in the moral effect it produces, even on those who might be expected to be, for professional reasons, least liable to such influences. A sudden outbreak is not unlikely to cause a quite natural mental perturbation in the minds of the military authorities. At such a time they look to the medical officer for guidance, and I need hardly say that they have every right to expect and receive it. The man who has a scheme already sketched out in his mind will be able to meet the sudden demands made on him better than the man who leaves everything to be settled at the last minute.

There are master-minds, no doubt, who can face any situation on the spur of the moment as it arises. As Athene from the head of Zeus, so from their teeming brains elaborate schemes leap forth complete to cope with any emergency. The ordinary man is not so blessed, and would do well to realize the fact in time. I would impress, therefore, as strongly as lies in my power, on all medical officers in charge of stations the advisability of drafting for private reference, as soon as possible after taking over charge, some plan of action in case of such an emergency arising. Just as every commanding officer has his defence scheme cut and dried, so every senior medical officer should have his sanitary defence scheme ready in advance and available for immediate use.

There is but little excuse for being taken by surprise, since some warning at least, if only short and slight, is as a rule given. To be taken both by surprise and unprepared is inexcusable.

I have not spoken about anti-cholera inoculation, since the present comparative rarity of the disease has rendered the necessity of such a precaution, taken generally, unnecessary. The method, however, exists, and the experience of Powell in Assam is strong evidence of its utility. In the case of troops compelled to keep the field in an endemic

area it might be necessary. Circumstances might even demand this precaution in the case of a large force operating on an infected trade route.

Here, however, it may be permitted to draw attention to an essential weakness of " prevention by inoculation." To protect against one disease, smallpox, is essential, against two, smallpox and enteric fever, reasonable. This we at present do as regards the single, and as far as possible as regards the double event. It would be possible, no doubt, to add a third to the list on emergency, but a further sequence might well make the soldier wonder with Macbeth, " What ! Will the line stretch out to the crack of doom ?" and conclude with him, " I'll see no further," which might have a serious effect on recruiting.

CHAPTER XX

PREVENTION OF INFECTIOUS DISEASES (*Continued*)

MALARIA.—Malaria may be taken as the type of that class of infectious diseases which are communicated from the infected to the non-infected man by the agency of a biting insect. As regards the British Army at the present day, it may be said to be the only member of the class with the prevention of which we are in any way concerned, yellow fever, the other important representative of the group, having long since ceased to be an important factor in the health of the army.

History of Malaria in the British Army.—Malaria played an important part in the history of every campaign in which the British Army took a share up till the end of the Napoleonic wars, even in Europe, and is still of importance both during peace and war in tropical climates. As far as the army is concerned, indigenous malaria has not been seen in the British Isles for many years, the last occasion being in Tilbury Fort in the year 1873. Since, however, these fevers are still said to lurk in remote nooks on the Eastern coast and in the Romney Marshes, and malaria-bearing anopheles are known to breed in the New Forest and Cheshire (Newstead), it might be necessary to take precautions against them in the case of any large concentration of troops in those districts. Rare, however, as malaria has now become in England, to the point of being a natural curiosity, it is important to remember that it was not always so. It is probable that the marshes on the Surrey side of the Thames were a couple of hundred years ago almost as deadly in this respect as the West Coast of Africa is at the present day. Occasionally, when the question of the suitability for occupation by troops of some station or other is being discussed,

objections are raised on the ground of its being inside what is called the "fever zone," which is defined as being below 4,000 feet or thereabouts. It is worth remembering that in 1710 Lambeth and Southwark were undoubtedly in the fever zone, and that if that zone were a purely orographical phenomenon they should still be in it.

The most important epidemic of malaria in the history of the British Army is that which occurred in the Walcheren Expedition. The size of the force implicated and the proximity of the locality to our own shores impressed, as was only natural, the public opinion of those days in an unprecedented manner. Nearly one-quarter of the 17,000 men employed died, and at one time two-thirds of the total strength was in hospital, the death-rate being twenty-five to thirty a day. The locality selected for debarkation was notoriously malarial, the season of the year the most unhealthy of the four, and there was no selection of the men. Other mistakes in plenty were made, but the three cardinal errors just noted should be remembered, because they furnish useful danger-posts for future guidance. The chief historical interest, however, centres around our numerous tropical campaigns, and of these I will only refer to those in Ashanti in the years 1864 and 1874. As regards the former, Surgeon-General A. A. Gore writes in his "Medical History of West African Campaigns": "It can hardly be called a war, as an enemy was never seen or a grain of powder expended. Our troops were defeated by disease, much of which was preventable." It may be said briefly that the entire force either died or was invalided, and the same fate overtook the reinforcements. In the 1874 expedition, on the other hand, the death-rate was 18·2 per 1,000, including thirteen killed in action. The campaign was, in a military sense, a striking and complete success. The force was carefully picked, local preparations were carefully made in advance, the best season of the year was selected, and the blow, when it was struck, was sent clean home without any delay. This expedition, in spite of the fact that it took place before the true cause of malarial fevers was known, or the foundations of the science of tropical medicine laid, might be taken as a model for the planning of all other campaigns in tropical countries. It is an excellent illustra-

tion of the value of a knowledge of military history in the practice of military sanitation. Twenty-one years later, observing the same rules, a second successful expedition into Ashanti was made, whilst in the very same year a French force in Madagascar—a not particularly unhealthy climate —through neglect of these rules, met the same fate as that which overwhelmed our troops in 1864. Malaria has also played a great part in our Indian campaigns, especially those in Arracan and Burma, but it would exceed the bounds of this work to discuss these. The campaigns I have already mentioned I have selected as furnishing certain useful data for prevention in war, and I will refer to these again later.

Prevention of Malaria.—In this, as in all infectious diseases, we have to consider the infected man, the germ, and the non-infected man. The connection between the three is, however, much simplified by the fact that a fourth factor is introduced, and that the path followed by the germ from the first to the second human being implicated is extremely narrow, being limited to the body of a certain species of mosquito, and to the female only of that species.

The infectivity of the infected man does not depend on any innate quality residing in him, or on any voluntary act of his own, but purely on the possibility of his being bitten by a particular species of insect. The danger to the non-infected man is similarly conditioned. The work of prevention is directed, therefore, entirely towards eliminating all possibility of the insect in question biting any man at all, either by destroying the insect, which is obviously the best method, or by interposing some mechanical obstruction between the man and the insect which will prevent the latter biting the former. Lastly, if for any reason these measures fail, we can by the use of drugs render the blood of the non-infected man an unsuitable habitat for the disease germ. This procedure possesses, however, the same essential defect as does prevention by inoculation, since it aims at protecting each individual separately, and not at protecting the community as a whole, and, therefore, all the individuals of which it is composed. In addition, as far as we know, it protects the individual against only one mosquito-borne infection, and if there are objections to the multiplication of inoculations, there are infinitely more

objections to prevention by polypharmacy. Lastly, whilst the protection afforded by inoculation lasts for a term of years, that supplied by drugging can be measured in hours.

Mechanical Protection against the Bites of Insects.—This can be supplied by surrounding the individual with an impervious screen composed either of metal or some textile material, which will allow free circulation of air, and at the same time place an insuperable barrier in the path of flight of the insect. It is, in fact, a method of filtration, and just as in the case of filtration of water, it is impossible to keep back the suspended particles without to some extent obstructing the free passage of the water, so here it is impossible to keep out the mosquito without to a greater or less extent interfering with the motion of the currents of air.

The materials used are either mosquito-curtains, which protect the individual during repose, or mosquito-proof gauze windows and doors, which protect him at all hours during which the insect is active. Curtains are in common use in all tropical and subtropical climates where mosquitoes are numerous. They are so familiar that any lengthy description is unnecessary. They should be large enough to have a sufficient margin to tuck in under the mattress, and it is advisable that the lower part, which may come into contact with the body of the sleeper, should be made, not of netting, but of calico, or else, as Ross advises, with a valance of netting in addition, to prevent the mosquito pushing its proboscis through the apertures. Before arranging the net in position for the night, search should be made in the angles at the top for any insect that may have taken shelter there after feeding during the previous night. Ross advises that there should be no opening in the net, and this is most important. Nets, as purchased, frequently have a flap-door which it is practically impossible to close completely. The mesh of the net is usually eighteen threads to the inch.

I would strongly recommend any officer living in a roomy bungalow to have a small mosquito-proof room built inside his bedroom—say 12 feet by 10 feet by 8 feet—large enough to hold his bedstead, an easy-chair, a bedside table, and a small bookcase. The walls and roof of the room should be either of netting or wire gauze on a wooden framework. With a small electric or hot-air fan he will be more com-

fortable in this room than under a mosquito-net, and he can spend the hotter hours of the "long, long Indian day" in comparative comfort.

Buildings may be rendered entirely mosquito-proof by the use of wire gauze in the doors and windows. The material may be either tinned iron, copper, or brass, the latter being somewhat more expensive. The suggestion of Wurtz, quoted by Ross, for the substitution of netting painted over with silicate of potassium for metal gauze is well worth remembering. In this case the mesh should be larger than that recommended above.

By any of the above methods it is possible for the individual or the household to secure mechanical protection against the bites of mosquitoes.

When we come to the question of protecting the soldier, the matter is less simple. The use of mosquito-curtains in barracks is absolutely out of the question in the hot weather in India. The inevitable obstruction to ventilation and the impossibility of using net frames of sufficient size at the same time as punkahs decides me definitely against them. In certain stations, no doubt, and at certain seasons of the year, they might be possible, but in those cantonments where the bulk of our army is stationed they would, except as an occasional method of protection, be out of the question. Mosquito-proof doors and windows would be less objectionable, but the former would be constantly left open, and the latter would be apt to be broken. During the hot, dry weather of Upper India gauze has the great disadvantage of collecting and holding dust. If the gauze were fixed in detachable frames this objection would be to a great extent removed. In any case, if gauze doors and windows are used, it would be necessary to introduce some more efficient form of fan than the common hand-pulled punkah.

A good current of air is, in fact, one of the best mechanical protections against the mosquito, and I think that the introduction of electric fans would be justified on this account alone.

The use of essential oils is occasionally resorted to with a view to keeping mosquitoes at a distance. To most people the sensation of heat that results is intensely uncomfortable, but for sentries and others who are necessarily exposed in

the open, and whose hands must be left unencumbered, this method of protection should be useful. The ordinary kerosene oil, which is everywhere obtainable in the East, acts very well in this direction.

Gauntlet gloves and veils were used by the Japanese in Formosa, and on occasion might be resorted to. They possess the very distinct disadvantage from the military point of view of obscuring vision and interfering with the manipulation of the firearm. Officers will do well to remember that the Wellington boot affords in evening dress a protection that the more strictly fashionable "pump" and thin sock fail in providing.

As regards the patient in hospital, the first step is necessarily isolation. This is now universally carried out. The next is protection by mosquito-netting or wire gauze screening over door and windows. The latter should be provided in all fever wards, to exclude flies as well as mosquitoes; but the window gauze should be, if possible, in removable frames, so that the windows may be taken out when neither of the insects noted is in marked evidence. The objections to mosquito curtains in hospital are very great. They obstruct ventilation, and are an intolerable nuisance from the nursing point of view. They should only be used where proper screening is impossible. Wire gauze is not open to the same objections in hospitals as in barracks, since there is not the same coming and going, and nurses and orderlies are more careful in the matter of closing doors than is the healthy soldier in barracks. In dusty weather all gauze should be wiped with a cloth soaked in weak disinfectant solution once in the twenty-four hours.

The Attack on the Mosquito.—All these precautions, with the exception of wire screening of doors and windows, are open to the objection that they aim at individual, not communal, protection. The latter is only effected by attacking the insect directly, and destroying it, either in its aquatic or its aerial period of existence.

I do not intend here to go into detail as regards the cycle of the mosquito's life. Suffice it to say that the stages of egg, larva, and pupa are passed in the water, that of imago in the air. During the stages of larva and pupa the insect needs not only water, but also air, and is, therefore, naturally

most vulnerable at these periods. Its movements are also considerably less free than when it exists in the fully-winged form, and, therefore, attack is more easily directed.

It is necessary to remember, as an item in general knowledge, that only mosquitoes belonging to a certain genus, Anopheles, are capable of acting as hosts for the malarial plasmodium, that not even in this genus are all the species so endowed, and that in any case only the female sex possess the quality. At first sight, then, it would appear that our destructive measures should be directed only against these special species, and in most textbooks a certain space is devoted to a consideration of their habits, especially as to the nature of the water, clear or turbid, running or stagnant, in which they prefer to live. I cannot myself see the necessity for such a meticulous differentiation. The mosquito, whether Culex or Anopheles, whether merely an annoyance or a danger, is assuredly under every condition *hostis humani generis*, and deserves so to be treated. Personally, I should incline to a cold scepticism if any officer assured me that he had destroyed all the malarial-bearing mosquitoes in a station wherein I suffered at all seriously from the bites of the common Culex.

These remarks apply, of course, only to the current anti-malarial work of the station, and the class of operations that can be undertaken by the local authorities without incurring serious expense. When it is a question of permanent improvements and large outlay, naturally the identity and habits of the local " malaria-carrier " need to be carefully studied.

The object, then, to be kept in view is the destruction of all collections of water in which mosquitoes can breed, and where this is impossible, the rendering of such collections uninhabitable as regards the insect.

The first method applies naturally only to such small collections as are contained in empty tins and bottles, casual rain-puddles, etc. ; whilst the latter step must be taken in the case of larger permanent sheets of water—irrigation channels, storage cisterns, and so on. To begin with, however, it is necessary to get a large scale-map of the station—on a scale, say, of 25 inches to the mile—on which every road, building, watercourse, and pond should be clearly

shown. A careful survey must next be made of the station, and any other fairly obvious breeding-grounds—*e.g.*, borrow-pits, rain-water cisterns, etc.—recorded on the map by any convenient conventional sign. If the season of the year be dry, then it is as well to take advantage of any casual rain-storm to identify localities where the water is apt to hang. Patches of wet cultivation, if allowed to remain, should also be noted. In many stations breeding-grounds peculiar to the station exists. Thus, at Bangalore, where large bosses of granitoid rock exist, it will be found that water collects in niches in the rock left by the partial removal of exfoliating layers. Stand-pipes often give rise to breeding-grounds in consequence of the drip of water from an imperfect valve.

The breeding-grounds having been as far as possible identified, the station should be divided into sanitary areas, corresponding most conveniently to the lines of the different units, and placed under the medical officers in charge of those units. It should be the duty of these officers to keep the map-sections relating to their various areas up to date, noting carefully any new temporary or permanent breeding-grounds that may come into existence. It will also be necessary to allot to each sanitary area a gang of workmen under a foreman, the establishment being proportioned to the size of the area. It will, perhaps, be necessary to take on extra hands during the rainy season, but the permanent cadre must be sufficient to deal with the permanent water. Some system of work must be laid down, but the details of this will vary with the station concerned. It is necessary to remember that the insect takes about ten days to develop from the egg to the imago, and spends a week in the larval stage, so that every breeding-ground should be dealt with once a week, but need not be visited oftener. The keynote of the whole campaign is intelligence first, and system next. Given these, the arranging of practical details is a task demanding only common sense and money. The former of these must be supplied by the officers concerned, the latter is a matter for the consideration of higher authorities. These last may or may not see their way to the necessary expenditure ; that is, after all, their affair. They most certainly will not see their way if they think the money is

going to be wasted in aimless and unsystematic fiddling with the problem.

In an Indian cantonment there is no great difficulty in the case of the barracks or the ground in their immediate vicinity. The trouble really arises in connection with private compounds, native bazaars, and the lines of followers. As regards the former, I have no doubt at all in my mind that the occupier or owner, if the house be unoccupied, should be made personally responsible for the breeding-grounds in the bungalow compounds. Some paragraph like the following should be inserted in Station Standing Orders (copied from the draft regulations drawn up for Mauritius by Ross) : " It shall not be lawful for any owner or occupier to allow mosquitoes to breed in his premises, or to allow the presence on such premises of any receptacle in which water is kept or may collect, unless such receptacles are properly protected from access of mosquitoes, or unless the water they may contain is treated in such a way as to prevent the breeding therein of mosquitoes, nor shall such owner or occupier allow on his premises any conditions which may in any way be favourable to the breeding of mosquitoes." The " civil " language used above may fitly in a military order be made somewhat more peremptory.

With regard to the better-class native there will always be a great deal of tact necessary, as in all other sanitary matters ; but in the followers' lines it should be fairly easy to enforce the rule as to the abolition of stagnant water.

One of the most usual breeding-grounds in private bungalows is the earthenware jar, or *ghurrah*, which is used to collect the outflow from the bathroom. This is usually emptied out inefficiently by the gardener for the sake of the flowers, but a scanty residue is always left, which is as a rule crowded with mosquito larvæ and pupæ. The garden well, rarely covered over, is also troublesome. Some form of insecticide is probably the best thing here if the well is used for irrigation. All unused wells should be covered over. " Pot-gardening " being the rule throughout India, numerous loopholes are given here for the mosquito, which need watching. The accumulation of large pot plants in or along the edges of verandas is a mistake, as they not only encourage

mosquitoes, but obstruct the passage of air, whilst the moisture of their frequent waterings is sufficient only to make the atmosphere close. Whilst on this subject, it may be as well to lay down that no high trees or dense shrubbery should be allowed near a house in India. The amount of protection which the former afford against the rays of the sun is more than counterbalanced by the closeness they engender.

Storage cisterns are rare, but when they exist should be netted over or oiled. A piece of wood or metal, heavily tarred and placed in the water, is a fairly efficient means of maintaining a scum on the surface of the small masonry cisterns which often exist in Indian gardens.

Large Ponds and Lakes.—These exist in many Indian stations, and when of considerable size add greatly to the amenity of the locality. When small—what would be called in England horse-ponds—they should be filled up or drained. The larger lakes are usually formed by artificially blocking up some natural drainage channel. One side, therefore, shows a steep bank, usually protected by a cement or masonry revetment. The water here is usually deep, except in very dry weather, and mosquitoes do not breed as a rule along this side, owing to the constant disturbance by the wind-fret of the ripples, and also the fact that fish and other aquatic foes are able to pursue them to the edge. A considerable extent of the margin, however, consists of a sloping foreshore, muddy, and poached by cattle when the water is low, or grass-covered during the wet season. In either case, mosquitoes are at liberty to breed freely in amongst the grass-roots or in the small puddles left behind by the retreating water in small inequalities, more especially in the hoof-marks. Dealing with the latter first, it is important to limit, as is done in Panama, the access of cattle to the water except at certain definite places. Here, the foreshore should be paved with cobbles (these are better than cement, which invariably gets broken up) for a sufficient distance. Throughout the rest of the margin of the tank the endeavour should be made to keep the water as deep as possible up to the edge. This may be done by building out the bank or else cutting it back. When the water recedes from the artificial bank it should leave only a flat, not a

shelving bottom, and this can be managed by cutting terraces in the bottom of the tank during the dry weather. In stations where the subsoil is either clay or laterite (and this in my experience in India covers the majority of cases that demand treatment) there need be no difficulty in the above. When the water in a very dry season retreats beyond all the artificial safeguards that have been arranged, then probably the surface will have got so small that oiling or other measures will have become practicable. Looking back on my Indian experience, I can only remember one station where it would be impossible to carry out measures on the above lines, and that is Meiktila, in Upper Burma. The Hoossein Sagar, in Secunderabad, the Ulsoor Tank in Bangalore, and the tanks in Umballa, to name a few instances, are too far from barracks to come into consideration.

Irrigation Channels.—In some stations irrigation is a necessity of human existence. I remember visiting the station of Meean Meer (now Lahore Cantonment) in 1905, when irrigation had been cut off. Malaria was no doubt very prevalent in that station prior to that change, but at least life was possible. Speaking quite deliberately, I feel justified in saying that the clouds of dust and the persecutions of sand-flies made life barely worth living under the new conditions. Irrigation, then, being a necessity, the question remains—How is it to be carried out ? Personally, I am of opinion that in such a case well irrigation is the solution of the problem. Irrigation from canals and irrigation from wells differ considerably from each other. In the former, extraneous water is brought into the station. The cultivator, it is true, pays a certain tax proportioned to the amount of water that he receives, but without casting any undue slight on the honesty of the native sub-subordinate who arranges these matters, I am under the impression that no extraordinary strain is placed either on his conscience or the pocket of the gardener in arranging an additional allowance. The inevitable consequence is flooding of the garden plots. On the other hand, if well irrigation is resorted to, every drop of water has to be dragged laboriously to the surface by bullock-traction, which necessitates a decidedly greater amount of personal labour on the cul-

tivator. Flooding is therefore prevented. But more important even than this, the water which is used for irrigation is no longer extraneous. It is merely shifted vertically from one part of the station to another, and very quickly finds its own level again. If irrigation is necessary, then let it be well irrigation. If canal irrigation is demanded, then constant watch should be kept to see that it is carefully regulated, and that any patch flooded is allowed to dry completely before another allowance of water is supplied. At the same time, every water-lead must be carefully watched, and all places, such as small backwaters below culverts, or other places where mosquitoes may find a breeding-place, well stirred up with a paddle or other implement once or twice a week, so that all collections of floating leaves, under and amongst which mosquitoes might breed, shall be satisfactorily disturbed.

I have mentioned merely a few points which my experience in India has shown me to be important. Every station has its own weak points, and it is the business of the senior medical officer to realize these, and see that the resultant danger is met.

Working on a system, and with a map, he need be no genius to effect this. Without a system and without a map, all his efforts will be useless. I except those Napoleonic geniuses who are so frequent in theory (their own) and so rare in experience (mine, and I venture to say that of their brother officers), who, by the mere light of nature, and that automatic grasp of the conditions which their intellects confer, are able to tackle any situation as it arises. I admire, I regret I am unable to imitate their success, and I fear I even retain a certain ungenerous scepticism as to its existence.

However energetic and systematic an officer may be, he need never hope to eliminate all the malaria-bearing mosquitoes, nor even all the harmless individual members of that family, in his station. It may be some consolation to such to realize that at least two species of Anopheles capable of bearing malaria still exist in considerable numbers in this country, and that even whilst writing this chapter within eighteen miles of London, I have had to repel the too urgent attentions of various members of the Culex tribe. A station can be malaria free without being mosquito

free, and life can be easily supported even where the gnat occasionally winds his sleepy horn, as long as the music is not too insistent.

The ingenious calculations of Ross have shown very clearly that if the disease-bearing anopheles are reduced below a certain proportion, malaria must inevitably die out, and the fact that these insects still breed in a considerable number of places in England is eloquent additional proof of the theory.

Malarial Records.—It is most important that a record should be kept of all cases of malaria occurring in the station, and their incidence noted on a map. A check can thus be kept on the operations of the various mosquito gangs, and any unrecognized breeding-ground traced.

Destruction of Adult Mosquitoes.—This is neither so easy nor so efficacious as destruction of the larvæ, partly because of the nimble flight of the winged insect, and partly on account of the fact that our efforts have to be directed largely to killing individual insects, and not to mass destruction, as when we deal with the breeding-places of larvæ.

Ross advocates the use of a small hand-net, and where the numbers are small a great deal can be effected in this manner. In hospital wards such a method of killing the stragglers that have passed the first defences of netting or gauze would undoubtedly be extremely useful.

Fumigation by means of sulphur, pyrethrum, or camphor and carbolic acid may be used, and would be advisable in the case of taking over a previously unoccupied bungalow. Barracks, which have been left empty during the hot weather, might conveniently be so treated before being occupied by troops coming down from hill-stations.

Mosquito traps were first suggested by Nuttall, and have been used in Dahomey by French officers. These consist either of holes dug in the ground, and so placed as to be sheltered from the direct rays of the sun, or else, in bungalows, of small boxes, painted black inside, or lined with black cloth. All such measures must, however, be looked on as merely palliative and secondary to a well-considered campaign directed against the larvæ.

Prophylactic Administration of Quinine.—This may be resorted to with advantage when other measures, such

as the destruction of the larvæ or adult insects, are impossible, or only applicable in an imperfect manner. It is most unscientific to rely on it as the main basis of prophylaxis in peace-time. I have already discussed this matter, and need not repeat what I have already said thereon. Personally I prefer the occasional administration of quinine in large doses to the constant taking of small amounts of the drug. Opinions are, however, about equally divided on the subject. In the former case 10 to 15 grains on Monday and Tuesday of every week; in the latter 5 grains every morning should be given. Men going out to shoot in specially malarious localities should certainly, if the exposure is to be for a short time only, start with a couple of good doses, followed either by a periodical repetition of the same, or the smaller daily dose.

Malaria in War. — The consideration of malaria in war resolves itself practically into a discussion of the conduct of a tropical campaign. Of these the Ashanti expedition of 1874 should be taken as a model. The keynotes of this campaign were careful preparation, followed by rapid execution, the actual striking of the blow being effected by a carefully selected European force, of which no other duty except that of marching and fighting was demanded. In all tropical campaigns the human enemy consists of savages, who, whatever their bravery, can be fitly encountered by men of their own race as long as these have the benefit of the superior arms and organization of a civilized nation. All the hard work and drudgery should be performed by locally raised levies, under the immediate supervision of European officers and a few non-commissioned officers. This rule would apply to all the non-combatant services— engineering, transport and supply, and medical to a very great extent. The proportion of natives to white men in the Ashanti expedition was as two to one; in the first expedition the numbers were about equal; whilst in the French campaign in Madagascar the proportions were reversed, the white force numbering 11,000, the native 3,800 only.

In selecting men for such an expedition all those with a bad malarious history, or with the plasmodium in their blood, should be excluded. In the case of officers it would be necessary to balance the advantages furnished by the

possession of some special qualification, against the possible danger to the other members of the staff of an infected individual in their midst.

The actual base of operations and the line of advance should be selected very largely on medical grounds, premising, of course, that there is any choice in the matter. A specially selected medical officer should be deputed to collect intelligence as to the health conditions of the locality, and to draft a scheme for antimalarial measures at the base. He should reconnoitre as far as possible along the intended line of advance, selecting the positions for permanent and temporary posts on the lines of communication.

It must be remembered that in a campaign of this nature the superiority of the civilized force on the purely military side is so great that it can afford to give away even considerable tactical advantages, whilst it cannot afford to take any chances as regards disease. This is more particularly the case as regards the base, which, in the case of the British Army, is almost invariably on the sea coast, where, therefore, the guns and searchlights of the fleet can be made available for local defence. Posts on the lines of communication should never be in proximity to a native village. Where, however, such a site is imperative on military grounds, the village must be destroyed by fire, the inhabitants, if friendly, being compensated appropriately.

The actual prevention of malaria must proceed on precisely the same lines as in peace—that is to say, the sick must be isolated, the healthy man protected from the bites of mosquitoes, and these destroyed wherever such a course is feasible. At the base itself, and to a less extent at the permanent posts on the lines of communication, the steps taken must approximate as closely as possible to those adopted in cantonments. In proportion as service conditions prevail, the measures adopted must also be modified. Night duties must be made as light as possible, and sentries relieved frequently. Every advantage should be taken of artificial aids to strengthen defences, and so limit as far as possible the service of security.

For troops continuously on the move the prophylactic use of quinine must be the main resource, and it is as well to remember that even when troops are halted it is

unnecessary to take active antilarval measures if the period during which they are intended to remain stationary is less than one week.

The Exanthemata.—The diseases included under this heading are not of frequent occurrence in the army in time of peace. They are, with the single exception of smallpox, rare in the tropics. At home occasional outbreaks of measles and scarlet fever occur, but the total amount of disability resulting from these diseases is not important. Thus, in the year 1909 there were only 575 admissions from measles and scarlet fever combined, with six deaths in the whole army at home and abroad, the ratios per thousand being 2·6 and 0·02 respectively; 494 of the admissions and all the deaths occurred in the United Kingdom, and 45 of the former in India. Smallpox accounted for 28 cases and 2 deaths; 19 of the cases were in India, and the rest in Egypt, the deaths being equally divided between the two. The figures for the quinquennium (1904 to 1908) do not differ appreciably from the above.

It is possible in time of war that an army consisting largely of young reservists, and collected from all regions of any European country, might show a considerable number of cases, especially immediately after mobilization. The evidence of the past is, however, inconclusive on this point. Thus, in the North and South War the Federal troops returned 77 cases of measles per 1,000 of strength in the first year of the war, whilst the Confederates had over 8,000 cases out of a strength of 58,000 men during the months of July, August, and September of 1861. In both armies the disease became less common as the war progressed, and the number of protected men increased. Scarlet fever was rare on both sides. In the Franco-German War these two diseases played apparently a comparatively unimportant part, no special notice being made of them in the official German report. In the South African War there were only 338 cases of scarlet fever, and 1,218 cases of measles during the whole of the campaign, a number which is quite negligible considering the length of the period included. On the other hand, the Boers suffered rather severely, which shows that there was no climatic protection.

In the case of war in Europe it is probable that the

relatively greater age of our reservists would be in our favour, in comparison with other armies. There would, however, always be a danger from young soldiers of the regular army returning from furlough shortly before the outbreak of hostilities. It is not unlikely that any concentration of territorial troops might show a considerable number of cases, since their age would render them more susceptible, and the force would consist of men drawn from a large area of the country. Some existent infection might be expected to be present, and should always be anticipated.

The prevention of these diseases (apart from smallpox, which is largely, of course, a question of vaccination) must be conducted on the same lines as that of any other infectious disease. The chain—infected man, micro-organism, healthy man—must be assumed to be the same, though the actual *causa causans* has not so far in any case been satisfactorily isolated. The mechanism of infection, whether direct by contact of the two individuals, by ingestion or inhalation, or indirect by the intermediate action of some insect, is, of course, still unsettled. This fact renders the actual procedure of prevention more difficult. We can only rely on early recognition of cases, and isolation of patients and possibly also contacts, and thorough disinfection of all clothing and bedding.

Early recognition is, of course, the most important of these steps, and here we are at once confronted with the difficulty that bacterial methods are not at our disposal in the present state of our knowledge. We must, therefore, rely on previous history. We do not know yet whether the "carrier" case is as common in these diseases as in those of which our knowledge is more extensive and complete. It is probable that "carriers" are not common, since fresh outbreaks due to the return to duty of men who have suffered from either scarlet fever or measles, and gone through the usual period of quarantine, have not been noticed. The history of contact, or possible contact, is, then, of chief importance.

As far as the regular in the ranks is concerned, we are fairly safe here, but not in the case of the reservist or the territorial soldier. The former is usually protected by age, but each man might be asked, on examination for fitness,

whether he has been lately in contact with the disease? It would be too sanguine to expect a truthful answer to the query. The good soldier would not admit the possibility, the bad one might use it as a loophole whereby to escape the performance of his duty. Information as to the existence of any serious amount of such disease in any depôt town or any large centre from which many men were likely to come might be procured by the military authorities from the Local Government Board, and units so affected might be quarantined for, say, a week, supposing this not to interfere with mobilization arrangements. It would be unnecessary to quarantine for longer than the minimum incubation period, since in the case of widespread infection the disease would be certain to appear amongst the most susceptible individuals who had been exposed to it. A certain risk would, of course, have to be taken. In no case must the smooth progress of mobilization be interfered with.

With regard to territorial troops, the danger will, I believe, be greater than with regulars for the reasons already given, but chiefly because of the enormous number of possibly infected areas from which the men will have been drawn. One of the earliest duties of the medical officer of a territorial unit on mobilization will be to verify the vaccination of his unit. Every man who cannot show signs of successful revaccination, or a record of the same, should be revaccinated or discharged as unfit for service. As regard scarlet fever and measles, the difficulty is greater. At the same time that the medical officer is satisfying himself as to the vaccination of his unit, he should inquire as to previous diseases so as to know the number of men protected by previous attacks. He should also try to get into touch with the medical officer of health for the district from which his unit is recruited, and ascertain whether either of the above diseases (or any others of the same class) have been lately prevalent in any part of the district. Men coming directly from any part known to be seriously affected must, if military considerations permit, be isolated. I say "if military considerations permit" because, once mobilization is ordered, these become paramount. The responsibility for the decision does not rest with the medical officer, but the officer commanding the unit, or the General commanding the brigade or division.

It is incumbent on the medical officer to place the facts clearly before such superior authority, stating exactly the degree of danger that he considers to exist ; the gravest error that he can fall into is over-stating the case so as to make things safe for himself. That is, of course, a very easy course to follow, but it is a grave dereliction of duty. The medical officer is the only man who can really appreciate the extent of the risk, and he must not shirk the responsibility that lies upon him, of stating it accurately and without exaggeration to the commanding officer.

If isolation is impossible, then the medical officer must make a point of seeing all men coming from infected districts every day. The first symptoms of coryza, or of sore throat, will justify him in sending such men into isolation for observation, and all such cases must at once, from that moment, be treated as actually infectious. Isolation in such cases means absolute isolation, not the partial isolation that I referred to in speaking of suspected " carriers " of enteric fever.

All sanitary officers, *à la suite*, should make a point of warning officers commanding units of the presence of disease of an infectious nature in any villages, towns, or farms in their district. This would naturally be done through the divisional sanitary officer, who should, in fact, himself make it his business to ask for such information.

I have been speaking of these being carried out immediately after mobilization, because the Territorial Army does not exist as a permanent force until that occurs, but I need hardly point out that every medical officer who is in charge of a unit should be possessed of the information as to vaccination and previous diseases long before that day arrives. The fact that the regimental system, under which medical officers actually belong to combatant units, still exists in the territorial army, makes this easy of accomplishment, and it is for these officers to justify their position, by recognizing that these duties exist not only in time of war, but also in time of peace.

The problem of how to deal with an outbreak of exanthematous disease amongst troops composing a part of a fighting force actually engaged in military operations is one of extreme difficulty. Looking at the question broadly,

it seems to me that we can come to one definite conclusion at least. The affected unit must on no account be kept at the base or on the lines of communication. Such a step would be more certain than any other to lead to dissemination of infection throughout the army. The conditions which obtain at the front are those least favourable of any to the spread of these diseases, since the men are to a great extent in the open. During a prolonged halt the unit concerned should be encamped as far apart from the rest of the force as can be managed, and all mingling with the rest of the troops restricted as far as possible. Suspicious cases should be isolated in a separate camp, and contacts carefully watched. Once the force begins to move, isolation of any one unit, especially of an infantry battalion, would be practically impossible, and the risk must simply be run. It would be out of the question to immobilize a whole battalion because one company had shown cases of disease. Whether it would be worth while to immobilize the peccant company is a question that must be settled on the merits of the actual case. The intercommunication between the different companies of a battalion is, of course, far greater than that between the different battalions of a brigade, and, logically, if a company were immobilized, the whole battalion should suffer the same fate. The line of separation should be drawn between the battalion and other battalions, not between one company and another. It would need a very serious outbreak to justify the withdrawal of a whole battalion from the fighting line : it could not be used on the lines of communication, therefore it seems to me clear that the fighting line is the best place for it. Actual cases must be isolated and treated in a special hospital, and on no account sent back along the ordinary route of evacuation. Medical officers in charge of effective troops must spare no pains in the endeavour to recognize incipient cases. All men with sore throat or coryza must be watched with the greatest care for any rise in temperature or access of other confirmatory symptoms.

CHAPTER XXI

DISINFECTION

During the passage of the disease germ from the infected to the non-infected man, it passes its interim existence in certain matters, some of which are, so to speak, accessible, and others inaccessible. Amongst the former are the clothes and bedding used by the infected man, and the air and surfaces of the room which he has occupied during his period of infectivity. Amongst these also may be included his discharges, fæcal and otherwise. Clearly, in preventing the passage of the germ from one man to another, it is necessary to attempt at least to kill it during the period that elapses when it is, so to speak, extra-corporeal, and this is accomplished by disinfection. Clearly, also, this can only apply to those matters which are, as I have said, accessible. In a great number of instances it is possible that the germ may take up, as it were, an unassailable position, and in such a case we are helpless.

The process of disinfection, then, aims only at killing the germ in the clothes and bedding, or on the utensils used by the infected man, or in the room occupied by him during his period of infectivity, but it aims at nothing less than this. Nothing short of killing can be called disinfection. This process of killing is effected in various ways, principally either by the operation of heat or the use of some chemical solution or other; but whichever class of process be used, it is necessary to remember that the object of our attack is not the matter in, or on, which the germ rests, but the germ itself. It is, for instance, no use to raise the temperature of an article of clothing to that point which we know to be the death-point of the germ unless we insure that the germ itself shall be heated to that point; in other words,

that the heat shall penetrate to every portion of the article concerned in which it is possible that the germ may be concealed. Similarly it is useless to attempt to disinfect a mass of fæcal matter by immersion in a disinfectant solution if we are unable to guarantee that the active chemical particles shall in reality penetrate into all the recesses of the mass, and thus come into contact with the micro-organism. This is often forgotten, and it is not infrequently the case that agents, particularly of a chemical nature, are used whose action on the surroundings of the germ is such as, in fact, to prevent their coming into intimate contact with the germ itself. The disinfection of organic discharges presents a case very much to the point. Any agent which depends for its lethal action on its power of coagulating albuminous matter may, if brought into use for the disinfection of sputum, fæces, and so on, act in reality as a protective instead of a destructive agent by causing the formation of a defensive coating of solidified albumin round the germ. It is true that in practice we do, quite justifiably, use such solutions for the temporary disinfection of the external surface of such masses of organic matter pending a more complete process, in order to prevent dissemination of infective particles from that surface during transport to the apparatus where the true destructive operation of disinfection shall be carried out. This procedure is only justifiable on the understanding that it is a purely temporary expedient adopted *ad hoc*, to be followed after the shortest convenient interval by a complete operation of disinfection.

Agents of Disinfection.—The agents used for the complete destruction of germs are chemical solutions and heat. Cold may also be used to render micro-organisms temporarily inactive, and in Nature this actually may occur when epidemics of infectious disease cease with the advent of cold weather. As a matter of fact, this result may equally well be due to the fact that the low atmospheric temperature numbs and makes torpid the insects, flies, etc., which are the efficient transporting agents of the germ.

Chemical Disinfectants.—These may be divided into two classes : (1) Those which act on the germ in virtue of its possessing vitality, in other words, the true protoplasmic

poisons ; and (2) those which depend for their efficiency on the fact that they are able to produce certain changes, as of oxidation, reduction, or coagulation on all organic or all albuminous matter indifferently of the fact whether it possesses vitality or not. The distinction between these two classes is of great importance. The true protoplasmic poison exercises a selective influence, and acts on living tissues and on them alone ; moreover, in so doing it does not to any material extent expend its powers. Having killed a certain mass of living organisms, it is still capable of further activity, in apparently undiminished strength.

On the other hand, an oxidizing agent acts as a disinfectant purely in virtue of the fact that it possesses a certain amount of readily dissociable oxygen, which can enter into combination with the tissues of the germ, and having parted with its oxygen during this process, it is *ipso facto* rendered inert, and useless for further action. In addition, it possesses no selective action, and is forced to part with its oxygen to the first oxidizable matter with which it comes into contact. This may be dead and harmless organic matter, or even some incompletely oxidized inorganic mineral ; in either case the oxidizing agent is once for all reduced and rendered ineffective. The essential qualities which a chemical disinfectant should possess are that it shall be capable of penetrating to the inmost recesses of the material to be disinfected ; and, secondly, that it shall be able to effect that penetration without losing its essential disinfective lethal powers. Oxidizing, reducing, and coagulating agents are, therefore, useless in the case of fæces, sputa, or any similar organic infective matters, except for surface disinfection. In selecting the class of disinfectant to be used, we should therefore be guided by the nature of the material that we wish to disinfect. The protoplasmic poisons are those which are most generally efficacious.

The most important of these are the phenol derivatives, carbolic acid, cresol, etc., which possess the additional advantage of a strong odour, and in warm climates of discouraging the presence of flies. In choosing any substance of this class for the disinfection of linen, it is important to select one that will not leave a stain.

Various patent preparations are on the market which

consist of emulsions of tar oils with soap or glue. The former have the advantage that they attack any greasy matter enveloping the germ, and thus enable the disinfectant particles actually to penetrate to the micro-organism which it is desired to destroy. At one time they were supposed to be immiscible with sea-water, or with strongly saline fluids, such as urine. It has been discovered, however, by Major Wanhill, that this difficulty may be overcome if the soapy emulsion is first mixed with about four times its bulk of fresh water. The effect produced is, of course, a merely mechanical one on the arrangement of the globules, of which the emulsion is formed. The soapy disinfectants are far more stable than those made up with glue. The latter separate out into layers after a very short period if allowed to stand in contact with air—as, for instance, in a half-emptied bottle or drum. Heat appears to accelerate the change. Very considerable agitation is needed to effect the formation of a satisfactory emulsion in these cases. The strength of a disinfectant is usually stated as what is termed its "carbolic coefficient." The figure of the coefficient denotes that one unit of the disinfectant in question possesses a disinfectant strength equivalent to that of a stated number of units of pure carbolic acid. As a rough guide to the original strength of the preparation, this coefficient is not without a certain value, but it must not be pressed too far. A difference of two or three in the figure of the coefficient is practically negligible. This arises from the fact that it is impossible to standardize with any degree of accuracy the organism used in the test. Different strains have different powers of resistance, and the same strain shows a different power according to the length of time during which it has been grown under artificial conditions. Again, though the broth culture is supposed to be grown under similar conditions and an equal amount of it taken on all occasions, there is no possible guarantee that the bacilli in the different specimens are in the same state of aggregation. One loopful may take up several clumps of organisms, while the next may take up comparatively few.

Accepting, then, the fact that the coefficient is valuable only as a rough method of grading disinfectants in relation to each other, there is the further objection that all phenol

emulsions for some reason or other gradually lose their strength in course of time, and this want of stability appears to affect more markedly those which possess the highest coefficients. A high coefficient glue preparation has the further drawback that the consistence is much more viscid, and that, in consequence, it is more difficult to effect a satisfactory mixture with water. In some cases a partial mixture only takes place, the cloudy effect produced at the surface of the receptacle used for mixing completely obscuring the fact that the greater bulk of the disinfectant has sunk to the bottom. It may be anticipated that in the hands of careless or ignorant subordinates a great deal of the disinfectant would be wasted in this way. A preparation having a moderately high coefficient—say, one of 10—is, on the whole, more easily handled and more reliable for service use than one with a coefficient of, say, 18. It must be remembered that the efficacy of a disinfectant depends not only on strength, but on the power which its ultimate molecules possess of penetrating to, and coming into close contact with, the micro-organism. This demands a state of very minute mechanical subdivision, which, with the higher coefficient preparations, it is difficult to obtain, or at least to guarantee.

Formaldehyde also acts as a direct protoplasmic poison. It is used either in the shape of liquid formalin, which contains 40 per cent. of pure formaldehyde, or in that of paraform tablets. The vapour may be evolved either by heating the tablets in one of the many forms of lamp in the market, or by the chemical interaction of formalin and permanganate of potash. The latter method possesses the advantage that no special form of apparatus is necessary, and also that all risk of fire is avoided. Liquid formalin is also used for spraying walls and other room-surfaces. The great drawback to the use of formalin is the extreme instability of the aldehyde and its liabilty to polymerization with the formation of inert solid paraformaldehyde. In addition, the vapour is extremely irritating to the eyes and nose, rendering the operation of "spraying" extremely irksome. When used as a vapour it is essential that the relative humidity of the air in the room should be about 70 per cent., and the temperature about 70° F.—conditions

not always easy of realization. It coagulates albumin, and therefore is apt to form a protective coating when used to disinfect fæces and sputa.

Amongst this class of poisons may be included those substances which, on account of their powerful acid or alkaline reaction, destroy bacteria. Of these, the most important is milk of lime, which is useful in the disinfection of foul drains, discharges, and garbage generally. Chloride of lime, which is of utility under much the same conditions, owes a part of its activity to the lime which it contains, though, when fresh, the chlorine which it evolves is the really important ingredient. Where a powerful deodorant is required, as in foul urinals, stagnant drains, etc., it is peculiarly useful.

Perchloride of mercury is an extremely powerful disinfectant, acting chiefly by its power of coagulating albumin. Unfortunately, its use is much restricted on this very account, and it is therefore useless for the purpose of disinfecting stools or other discharges. It fixes any stains of blood, etc., that may happen to be on linen, and it attacks unprotected metal surfaces. In military practice it should never be used outside the hospital. The absence of any distinctive odour or appearance renders it an extremely dangerous substance for use in latrines in barracks or elsewhere, and though I am quite aware that it has been used in many stations in India to add to the stools in barrack latrines without any accidents occurring, the practice is, I consider, one fraught with the greatest danger.

The drawback to the use of all chemical disinfectants is the impossibility of insuring complete penetration to the innermost recesses of the substance to be disinfected. Where heat cannot be applied—as, for instance, in the disinfection of room-surfaces—or where the proper apparatus for its adoption in the case of clothing, etc., is absent, then chemicals must be used. They may also justifiably be employed for the temporary disinfection of bed and body linen or excreta, pending the application of heat. They should never be used for the ultimate disinfection of any discharges, fæces, pus, etc., since heat in the form of incineration or boiling is practically always available for this purpose.

Disinfection by Heat.—Heat may be employed either in

the form of dry or moist heat. In the former we trust to incineration or dry air, in the latter to steam or boiling water. The applicability of dry air is limited, owing to the fact that it is an extremely bad conductor. If the substance to be disinfected is bulky it is impossible to guarantee that the entire mass shall be raised to the thermal death-point of the disease germ without heating some parts of it to such an extent as to char or even set fire to them. It cannot, therefore, be used for the disinfection of clothing and bedding in bulk, and its utility is limited, in fact, to the disinfection of certain small articles.

Incineration should be used for the disinfection of all matters whose destruction is a matter of no moment—*e.g.*, old clothes, soiled rags, etc.—or for that of fæces or other discharges whose destruction is on general grounds advisable. This is undoubtedly the most complete form of disinfection, since it insures the destruction of the germ by effecting that of the matter in which it is resting. On service it should be practised extensively in the disinfection of clothing of men admitted to hospital with infectious disease, especially of an intestinal character.

Moist heat is used most simply in the form of boiling. Where it is inconvenient to incinerate excreta or sputa, etc., in the immediate vicinity of a ward, or where it is desired to disinfect at the same time the bed-pan, spittoon, etc., in which they are contained, boiling in the ward annexe may be advantageously resorted to. The receptacle, with the infective matter still in it (to which some convenient chemical disinfectant may be added with a view to minimizing nuisance), should be immersed in boiling water, and the whole left there for five to ten minutes. Washing-soda added to the water will materially assist in cleansing the utensil. Linen clothing may be disinfected by boiling, in the absence of any more convenient form of steam disinfector, but woollen materials shrink in the process. In general, however, and where the proper apparatus is available, moist heat should be used in the form of steam.

Steam may be applied either as current steam or under pressure, according to the apparatus available. It may also be used as saturated steam or superheated steam—terms which demand a short explanation.

Saturated steam is steam at such a temperature and under such a pressure that the slightest decrease in temperature or increase in pressure will cause condensation. Thus, steam as it issues from the spout of a boiling kettle is saturated, and the decrease in temperature resulting from its contact with the outer air immediately causes condensation, and the visible appearance of what is commonly known as "steam." Condensation would equally occur if the steam, though still kept at its original temperature of 212° F., were submitted to a pressure greater than that of the atmosphere at the time and place of its generation.

Superheated steam is steam which, having been produced at a certain pressure, is artificially heated without the pressure being at the same time raised in corresponding degree. If, for instance, the steam issuing from a kettle were led through a pipe heated in a flame to, say, 215° F., the steam would be superheated to that degree, and could not condense, the pressure remaining constant, until these 3° of superheat were removed. The steam would, however, remain saturated if at the same time as the superheat was added the pressure were correspondingly raised. It would then condense at once if the temperature were diminished to, say, 214° F., the pressure remaining constant. Superheated steam in the presence of water always tends to become saturated by taking up moisture.

Saturated steam, whether current or under pressure, possesses enormous penetrative power, owing to its power of condensation. When any volume of steam passes into the form of water by the process of condensation its bulk is reduced in the proportion of 1,500 to 1, and this occurs, as already stated, on the slightest decrease of temperature. Thus, if steam is passed into the interstices of a blanket, say, it immediately condenses, and the resulting diminution in bulk permits of the entry of more steam until the entire fabric is saturated with water. At the same time, moreover, as it condenses the steam parts with its latent heat to the blanket, until eventually by the time that the blanket is saturated with water its temperature is raised to that of the steam—viz., 212° F., at which point it can be maintained by simple artificial means. This is, in fact, the process of disinfection by means of current steam, and there

is no more efficacious method of disinfection, considered simply as a means of killing disease germs. For small quantities of clothing it can be used with great advantage in the simple form of a Koch's steam sterilizer.

The great disadvantage, however, of this method is that the clothing is completely saturated with water, which may cause shrinking in the case of woollen materials, and in any case, if many articles of bedding or clothing have to be dealt with, great difficulty in handling. To avoid this last it is necessary to employ some means whereby the disinfected clothing shall be dried inside the apparatus, and this can be done by the passage through it of dry hot air or superheated steam. Either of these will take up the moisture still remaining in the material, but the latter is the more generally used, as being less likely to injure the fabric, and more easily manipulated.

The Thresh disinfector shows such an apparatus in a very simple form. In this disinfector steam is evolved at atmospheric pressure from an aqueous solution of chloride of calcium, with a boiling-point of 220° F. The slight amount of superheat present is readily got rid of either by convection or by the taking up of moisture from the clothing, etc., which has to be disinfected. The steam, now having become saturated, condenses, and this process continues until the entire mass is raised to a temperature of 215° F., the heat of the steam given off. The steam, being now no longer able to condense, is turned off, and dry hot air used to take up moisture from the saturated clothing, and thus gradually to dry them. The apparatus is handy, needs no skilled supervision, and is easily worked, but the process is, comparatively speaking, a lengthy one. For dealing with small parcels of clothing or bedding it is extremely convenient. A portable form is made, which would be useful under certain conditions of field service where good roads were available.

Where larger amounts of infected material have to be dealt with, some form of pressure disinfector must be used, of which several types exist. The general plan of construction and working is much the same in all, and the following account merely gives the main lines of one such as the Washington Lyons, without reference to mechanical details :

The disinfecting chamber consists of a jacketed cylinder constructed to resist a pressure which may amount in the largest patterns to 32 pounds to the square inch. The material to be disinfected is run into the cylinder on a travelling carriage, and the door firmly clamped. The jacket is filled with steam at a temperature of, say, 130°, whose function is merely to heat the walls of the cylinder and its contents. The cylinder chamber is then filled with saturated steam at a temperature of 120° and a pressure of 122 pounds to the square inch. The pressure must naturally correspond to the temperature, since the condition of saturation depends on the balance of these two being maintained. In order to facilitate the penetration of the steam into the interstices of the material, it is usual to create a partial vacuum in the cylinder by the action of a steam jet, and this process may be repeated more than once. The saturated steam naturally condenses on the clothing in the cylinder, which is at a lower temperature, but the walls being at a higher temperature, the steam in the immediate contact with these becomes gradually superheated. In the course of a few minutes the entire mass of clothing is raised to the same temperature as the incoming saturated steam, which is therefore no longer able to condense. The jacket, however, being heated to a greater temperature than this, the entire mass of steam in the cylinder becomes gradually superheated, and therefore takes up from the clothing the water resulting from the condensation of the saturated steam. When the process is concluded the material in the cylinder is not only disinfected but dried, and can then be removed.

In actual working the different steps are not separated from each other as clearly as above described, since different portions of the mass to be disinfected may at any one time be at different stages of the process. The essential principle to be kept in mind is that the saturated steam is used to procure penetration and disinfection, and is then superheated to complete disinfection and effect drying.

In the Equifex apparatus the pressure is only about 10 pounds to the square inch, and drying is effected by dry hot air.

The selection of one type or the other depends on the

amount of work to be done, the amount of money available, and the presence or otherwise of skilled artificers. High-pressure boilers are only needed for large installations, are expensive, and need trained supervision. Where the amount of work to be done is comparatively small, where money is an object, and skilled workmen are not available, then a low-pressure or current steam apparatus must be resorted to.

It must be remembered that the disinfection of—that is, the killing of disease germs in—clothing by the means of steam is just as feasible with simple apparatus as with the most complicated. The latter, no doubt, saves labour, and facilitates the process, but that is all. Its absence is no excuse for neglecting the operation in some simpler form.

Steam disinfection in the field is always a difficult matter. An excellent portable form of steam disinfector is described in the *Journal of the Royal Army Medical Corps* for July, 1911, by Lieutenant-Colonel C. R. Aldridge. In this the clothing is packed in a box, which communicates by means of a pipe with a simple steam generator. This apparatus has given good results on trial at Aldershot, and possesses the advantage of being suitable for pack transport.

Room Disinfection.—It is usual to disinfect the rooms that have been occupied by persons suffering from infectious diseases, and since for such a purpose the use of heat is practically out of the question, we have to resort to chemical solution or vapours. The use of vapours, or fumigation, is a custom so sanctioned by practice that it seems almost sacrilegious to question its necessity or efficacy ; but, nevertheless, before discussing its use, it seems advisable to consider what it really is that we wish to disinfect when we disinfect a room, or, in other words, in what part of the room do we expect to find the germs which we wish to kill. Clearly the germs may either be floating in the air of the room or resting on the different surfaces—that is, on the furniture, hangings, walls, ceiling, or floor. When the germ theory of disease was first introduced, and before the actual particulate nature of the poison was clearly recognized, it was believed, and justifiably so, considering the state of our knowledge at the time, that the *materies morbi* actually floated in the air of the sick-room, and fumigation was

logically practised with a view to destroying that poison in the air. Such a theory can hardly now be supported. It is well known that in a closed room, free from draughts, all bacteria present in the air will, after a very few hours, have either fallen to the floor or come to a rest on the furniture or the walls.

It is clearly unnecessary, therefore, to disinfect the air of a room which has been closed for even a short time. The surfaces are the parts of the room which demand disinfection. Now, obviously those parts of the surfaces which are the most likely to be dangerous are the corners of the room, the crevices in the floors, or the furniture, since these afford shelter to the germs. The least dangerous areas are the open surfaces of the walls, etc., exposed to the light and air, and in the case of the floor to the mechanical attrition of human traffic. Unfortunately, it is just these nooks and corners which are the least accessible to the action of vapours. If one tries to imagine the condition of a room in which a large amount of disinfectant vapour has been evolved, it is easy to understand that whilst the open surfaces of the walls, etc., will be freely exposed to the action of the chemical there will be numerous dead angles to which the fumes will not penetrate. These may be many or they may be few ; their number will be largely a matter of accident. They will depend also on the humidity of the atmosphere, the heat developed during the evolution of the fumes, and the air-currents thus engendered, and other factors.

He would be a bold man who in any particular case would venture to say there was no such inaccessible spot in a room. Disinfection of the surfaces of a room by means of fumigation is, therefore, in my opinion, not even in theory possible, since it must inevitably be incomplete. In actual practice it is, I believe, almost useless, since it leaves untouched those parts of the room which need the most special attention—in other words, the nooks and crannies.

There is even a further difficulty in the way. It is very doubtful if isolated bacteria—separated, that is, from any sheltering adventitious organic matter—would survive long on the surfaces of a room. Even if they were able to do so, it is practically certain that what we have to deal with are not isolated individual micro-organisms, or even aggrega-

tions of such, but small masses of dried sputa, pus, fæces, etc., in which bacteria are lodged, and by the substance of which they are sheltered. The disinfectant has not, therefore, to attack the naked germ, but to penetrate to the interstices of these small particles of organic matter, and kill the germ therein embedded. In the absence of moisture this is practically impossible, and one of the conditions precedent for fumigation is, therefore, the maintenance of a high degree of humidity in the atmosphere of the room.

In fumigation with a chemical vapour we are, therefore, not using the disinfectant chemical in the form most suitable for the purpose which we desire to effect. In view of this fact, and of the almost absolute certainty that the vapour cannot penetrate into the corners and crevices where the infective matter is most likely to lodge, I believe fumigation to be in practice useless as a method of disinfection.

Coming next to consider the surfaces of a room, it is important to decide which of these really need disinfection, Pathogenic germs are, as we know, in some cases, though not in all, endowed with a certain amount of motility. This word can only, however, be applied to them in the microscopic sense, and it is hardly conceivable that any germ should of its own mere motion travel from the bed of the sick-room to any distant part of the room. The surfaces which demand disinfection are, therefore, those which are close to that part of the room occupied by the infected man, and, briefly, it may be said an area equivalent to about 2 yards all round the bed, and about 6 feet up the wall. In a small room this, of course, includes the entire floor-space, but in a large apartment—*e.g.*, a barrack-room —only a comparatively small portion of the floor is affected.

What we have to disinfect, therefore, in a barrack-room from which a case of infectious disease has been removed is the floor under and for 6 feet all round the bed of the man concerned, and also any furniture included in that area, together with a corresponding extent of the wall to the height of 6 feet. To effect the disinfection of this area we must employ some agent which shall insure that the disinfectant chemical used shall penetrate into every corner and cranny in a form in which it can actually reach and come into contact with the individual germ, not merely

with the outside surface of the dried mass of organic matter in which it is contained. To attain this end I know no means more efficacious than hot water, in which some suitable disinfectant has been dissolved in sufficient quantity, a plentiful supply of soap, and a scrubbing-brush, the whole applied with what housewives term "elbow-grease." In short, if the floor and walls to the extent noted above are thoroughly scrubbed in the above manner, I believe we shall have disinfected all the surfaces of a barrack-room that demand disinfection, and we shall have done it in a thorough manner.

A barrack-room differs from other rooms in the fact that it is not only much larger, but also much freer from superfluous furniture and hangings. Whatever æsthetic advantage these may possess, they certainly do not facilitate disinfection, and the proverbial bareness of a barrack-room gives it in this respect a great advantage.

In the case of married or officers' quarters, we are dealing with small rooms, containing furniture and hangings, and these last demand separate treatment. All curtains, carpets, etc., should be sprayed with formalin, and then taken away from the room for further disinfection. The furniture should be scrubbed with disinfectant before being removed, care, of course, being taken in the case of inlaid or polished articles not to cause any injury. The room having been cleared should then be thoroughly scrubbed, as already described. In short, the quarter should be thoroughly "spring cleaned," to use a well-understood and familiar phrase.

It would probably be advisable in the case of a bedroom to repaper the space immediately behind the bed, or in the case of a small room to repaper throughout. The use of paper in sleeping apartments should, however, be strongly deprecated, and that of some washable distemper substituted.

I would impress on every young officer in charge of effective troops the importance of supervising in person this process of disinfection. It is laid down in regulations that it shall be carried out by men of the Royal Army Medical Corps, so that the responsibility for its execution is no longer divided, as it used to be, between the Medical,

Engineer, and Barrack Departments, but it will be done much more thoroughly if an officer is present.

The best disinfectant to use for this work is one of the phenol group, the regulation substance being saponified cresol.

Disinfection of walls can be carried out by means of a formalin spray if it is desired to reach to a higher level than 7 feet or thereabouts. A spray possesses, however, no particular advantage over a mop, and is considerably more tedious in manipulation. It has, however, an "up-to-date" appearance, which doubtless produces a correspondingly good moral effect.

In cases where it is desired to use fumigation, either formaldehyde or sulphurous acid may be used.

Formalin vapour can be evolved either from tablets or some patent preparation, of which a large number exist in the market, by means of a lamp. The number of these is legion, and they all doubtless possess considerable efficacy —that is to say, they evolve a vapour which will inevitably destroy any bacillus with which it comes into contact, if it can effect that contact. They all possess the drawback that their use entails the leaving in a closed-up room of a lighted lamp. The danger of accident is no doubt small; still, it exists. A safer and more easily carried out process, demanding no special form of apparatus, is the evolution of vapour as the result of the chemical interaction of formalin and permanganate of potash. These can be simply mixed in any ordinary earthenware basin, and allowed to stand in the room. This method should always be used, in my opinion, in the Service.

Formalin vapour will not exercise its disinfectant action except under certain conditions of moisture and temperature. The air must possess at least 70 per cent. relative humidity, and be at 70° F. This at once places it out of court for general use in barracks. An ordinary barrack-room, built to contain twelve men, possesses a cubic capacity of 7,200 feet. All windows and doors must, of course, be tightly closed, and in addition the chimney must be blocked up. The problem of how to maintain a temperature of 70° F. for four hours in such a room without a fire would tax the resources of the most ingenious during at least nine months of most years in this country.

Formalin may be used to disinfect clothing, in stations where a steam disinfector is not available, in the following manner: The articles should first be well sprinkled with water, and then hung up in a wardrobe, paper having first been pasted over all chinks and openings. The wardrobe should be placed in a room near a brisk fire, and formalin vapour evolved inside the cupboard by pouring commercial formalin on to crystals of permanganate of potash. In a warm climate on service it might also be used to disinfect tents and ambulance waggons, the canvas of the tent or that of the waggon tilt being first thoroughly wetted with water. Thorough swabbing with a solution of any of the phenols would in all probability be equally efficacious.

Sulphurous acid can be evolved from the combustion of sulphur, but is more commonly supplied in the compressed form in cylinders. The atmosphere must be completely saturated with moisture, but temperature conditions are immaterial. The process is simple, and in the latter case free from danger of fire.

In extreme cases heat may be used for the purpose of room disinfection, but the process is not applicable to any but the rudest habitations. In the case of native huts which it is considered necessary to occupy on service, this method might be employed to destroy fleas or ticks. The floor should be strewed with any cheap fuel, such as cow-dung cakes, litter, etc., and this material set fire to. If care be taken it is possible to disinfect even thatched huts in this way with but slight danger from fire, though, of course, this danger must be guarded against. Since resort to such shelter is only likely to be necessary as a protection against heavy rain, the very conditions which necessitate the process will tend to render it safe.

Conclusion.—Disinfection is distinctly one of those operations which are at once simple and difficult. The simplicity consists in the facts that the object is merely to kill a definite living organism, and that the agents at our disposal for that purpose are almost infinite in number. The difficulty lies in the fact that it is often very hard to bring the agent into actual contact with the organism, and even more so to be certain that none of the germs which we

desire to destroy have managed to escape the action of the disinfectant process.

In any one case the sanitary officer must satisfy himself as far as he possibly can that all the germs have been subjected to the lethal process. He must on no account assume that because he has gone through some elaborate method of procedure or satisfied the requirements of some complicated ritual he has therefore necessarily effected his object.

CHAPTER XXII

SANITATION OF THE BATTLE-FIELD

The difficulties which beset the path of the sanitarian in the field are naturally enormously increased when the army is in immediate contact with the enemy or actually engaged in one of those long-drawn-out battles that it is to be expected will characterize future wars.

The immediate vicinity of a hostile force, with the incessant vigilance and extra strain that it entails on the troops, must inevitably play havoc with any complicated schemes of sanitation. It is on such occasions that the benefit of previous training comes into play. An army, the individual officers and men of which have been taught the importance of sanitation, will undoubtedly have a great advantage over an army whose members are careless or untaught in this respect. More especially will this be the case when the force is either stubbornly holding a defensive position, or engaged in a prolonged siege, or in an attack on such a position held by the enemy. In either case it will be practically out of the question to expect the individual soldiers to do much in this direction. In a besieged town or defensive position the civilian population that still remains must be encouraged, or if necessary forced, to undertake the execution of sanitary fatigues. The same may be done by the attacking force, though it would be unwise to allow members of a local and possibly hostile population to penetrate to the more advanced lines of the attack. In any case, however, much must be left undone, and the conditions under which a force closely engaged with the enemy, and fighting with modern weapons, will have to live, must inevitably be such as practically to prevent sanitary work being carried on. As a result, after a battle the state of

affairs will be such that very active steps will have to be taken if illness is not to break out, not only amongst the civil population, but also amongst the sick or wounded, whose condition is such as to prevent their removal from the vicinity of the engagement. In this country it is fairly certain that if the conduct of the operations remained in our own hands, the supervision of the necessary work would be entrusted to the local authorities, sanitary and otherwise. Sanitary officers on the *à la suite* list would undoubtedly find a considerable field for activity here. The matters to be disposed of would be not only the dead bodies of men and horses, but also the accumulation of excreta, broken meats, etc., the result of the continued occupation of a comparatively contracted space by a population perhaps a hundred times the size of that which ordinarily inhabits that area. Since the inhabitants of the locality would naturally be the people most interested in the cleansing of the battle-field, they could very fitly be called upon to assist. Trained soldiers, whether officers or men, would be too valuable to be spared on such an occasion from their duties at the front, and a well-organized sanitary service under the local authorities would constitute a distinct national asset. The first step would be to tell off the ground in definite areas, and entrust the work to definite parties of men under some locally recognized leader. Their duty would be to bury all accumulations of filth or garbage *in situ*. Time would not allow of these matters being collected for cremation, and shallow burial would be quite sufficient. They would also have to collect the bodies of the dead in groups for burial or cremation.

Undoubtedly the best method is cremation, and it is probable that in the case of the dead of an enemy fighting in this country we should, where possible, adopt this measure. As regards our own men, sentiment would probably prevent any such course, and the only resource then would be burial in large graves. Military trenches might be used where present. Pits should be dug about 10 feet deep and 7 feet broad, so that the corpses may be laid across the trench. Before placing any bodies in the grave some brushwood should be put down to facilitate drainage, and the corpses laid on the top of this to a distance of 3 feet, but not less,

from the surface. The earth should then be carefully heaped over the mass, a record being kept of the numbers and other particulars of the men buried in each spot. These duties will devolve very often on medical officers of stationary and other hospitals, and I need hardly remind you that every care should be taken as regards identification of bodies. Every soldier in a civilized army is provided nowadays with an identification disc, and these should be carefully kept until they can be forwarded to the proper authorities—presumably in case of war in this country, to the Adjutant-General at the War Office. These are not, it is true, strictly sanitary duties, but since they will so often devolve on medical officers and sanitary officers, especially those on the *à la suite* list, who will certainly be entrusted with the sanitation of any battle-field in their particular neighbourhood, the divergence is justifiable.

When burning is feasible—and in the case of a thickly populated country like ours it may be absolutely necessary in the case of the bodies of the enemy—it may be practised in various ways. One method is to make a large pyre of wood and brushwood or other fuel, in which are hidden layers of corpses. This method was adopted by the French in the wars of the Napoleonic era.

After Sedan, in 1870, cremation was resorted to with a view to destroying the corpses already buried, but not sufficiently covered over. The following procedure was adopted: The earth was first removed until a dark fœtid layer in immediate contact with the dead bodies was reached. This was watered with a solution of carbolic acid, and then the mass of putrefaction was completely uncovered. This was then sprinkled with chloride of lime, after which tar was poured over it and allowed to penetrate in between the different layers of corpses. The tar was set alight by means of straw moistened with petroleum, and as a result of the use of this last ingredient the fire was enabled to spread through the entire accumulation of corpses. The heat rapidly became so great that it was impossible to approach within 15 feet of the furnace, and in a little over an hour the contents of the most crowded trenches were reduced to about one-quarter of their original bulk. This, of course, would be largely due to evaporation of moisture. The residue

consisted of calcined bones contained in a resinous magma. The earth forming the walls of the trench, having been exposed to such an elevated temperature, was freed of all cadaveric odour. A dense smoke was formed, which produced blisters on the exposed skin surfaces of the workers. Gloves and veils should therefore be provided to people engaged in this operation. The flies which infested the ditches were all destroyed at the same time.

The Americans at Santiago, in 1897, used cremation to dispose of the bodies found unburied when the town was occupied. They adopted a plan similar to that used by the French in the Napoleonic wars already alluded to. Incineration is not, therefore, impossible, even using primitive means, and this possibility should always be kept in mind, especially in cases where burial has been inefficiently carried out, and a serious nuisance is likely to be caused. With regard to cremation, one word of warning must be issued. Incomplete cremation—that is, cremation undertaken without very careful preparation—and an abundant supply of fuel—is worse than useless, both on sanitary and sentimental grounds.

The bodies of animals present considerable difficulty, owing to their greater bulk. The usual plan, if burial or complete cremation is impossible, is to eviscerate the body, bury the entrails, and then light a fire in the cavity of the corpse. Fighting in civilized countries, one has always the advantage of a considerable supply of civilian labour, and, since the local inhabitants are the people most interested in the proper cleansing of the battle-field, they can, as already said, fairly be impressed into the service.

APPENDIX

A.—SCALES OF FIELD-SERVICE RATIONS.

Army.	Protein.	Fat.	Carbo-hydrate.	Calories.
Great Britain (biscuit and tinned meat)	180	49	510	3292
,, ,, (bread and fresh meat) ..	179	50	501	3255
Germany (ordinary)	101	79	489	3147
,, with increase of compressed vegetable portion	108	82	537	3401
,, with increase of meat portion	117	101	489	3413
,, with increase of both meat and vegetable portions ..	120	104	537	3667
,, South-West African Campaign	172	132	651	4602
France (*normale*)	124	64	518	3340*
,, (*forte*)	141	72	560	3651*
Russia	173	29	964	4929
Austria	108	42	458	2702†
	123	39	426	2620†
America	167	110	608	4199

* Including energy-value of spirit ration.
† Difference depends on nature of vegetable issue.

B.—TABLE SHOWING THE COMPARATIVE VALUE, TOTAL FOOD CONSUMED, AND TOTAL ENERGY EXPENDED: FIRST EXPERIMENTAL MARCH.

Day.	Total Food Consumed.		Total Calorie Value of Food Consumed.	Total Calorie Value of Energy Expended.	Remarks.
	Ration Scale.	Extras.			
1st	2	Cheese sandwich	71900	84403	
2nd	3	Nil	58600	83507	
3rd	1	,,	59260	69066	
4th	1	,,	59260	86155	
5th	1	,,	59260	88636	
6th	1	Rum ration	63660	83547	
7th	4	Nil	62020	60000	
8th	4	,,	62020	66924	
9th	4	,,	62020	83948	
10th	4	Whisky ration	66580	90533	
11th	4	Nil	62020	84108	
12th	4	,,	62020	87316	
13th	Nil	,,	Nil	Nil	
Total			748620	968143	
Average per man			37431	48407	
Average per man per day ..			3119	4034	
Deficiency per man			10976		
Deficiency per man per day ..			915		

The days are counted from 9 a.m. on Monday, October 11th, to 9 a.m. on Saturday, the 23rd. All work, internal and external, done and all food eaten during the period of twenty-four hours between 9 a.m. on the 11th and 9 a.m. on the 12th are included under the first day, and so on. The march performed on the 23rd is not included, as this was carried out after 9 a.m. on that day, at which hour the terminal weighing was recorded.

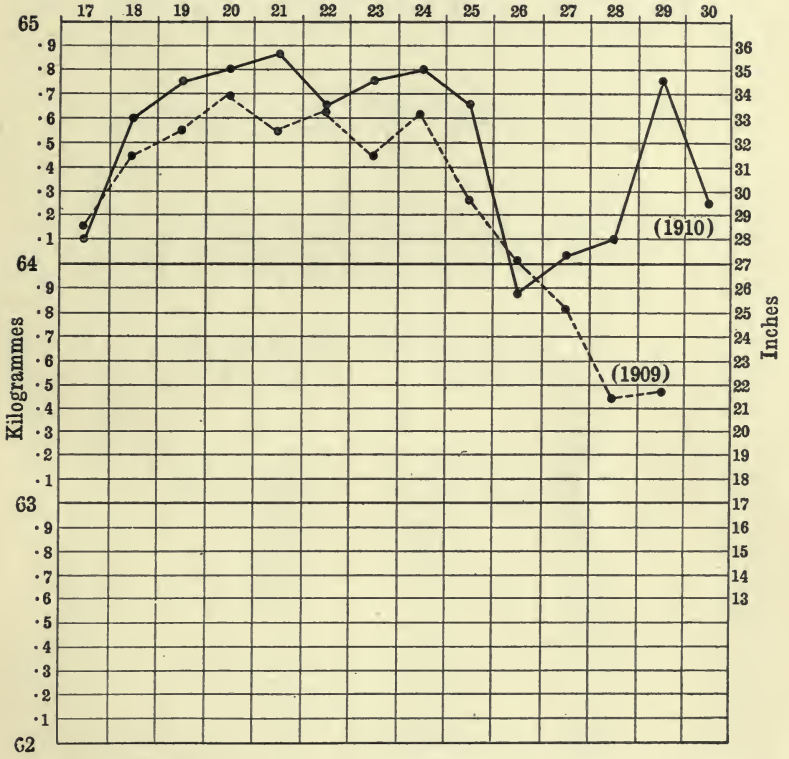
C.—TABLE SHOWING RATION SCALES, FIRST EXPERIMENTAL MARCH.

		Weight in Grammes.		Moisture.	Protein (N × 6·25).	Fat.	Carbo-hydrate.	Calories.
		Nominal.	Actual.					
Ration Scale No. 1: Corned beef, biscuits, potatoes, jam and grocery ration (47 oz.)	Corned beef, 1 lb.	453·60	336·00	183·28	100·59	42·50	—	808
	Biscuits, 8	453·60	484·00	35·42	75·31	6·67	361·35	1853
	Potatoes, ½ lb.	226·80	226·80	141·97	4·08	0·22	33·32	154
	Strawberry jam, ¼ lb.	113·40	88·60	15·45	0·61	—	68·94	285
	Sugar, 2 oz.	56·70	49·30	—	—	—	46·83†	192
	Tea, ½ oz.	14·17	19·23	1·92	—	—	—	—
	Salt (dry),* ½ oz.	14·17	13·93	—	—	—	—	—
Totals		1332·44	1217·86	378·04	180·59	49·39	510·44	3292
Percentage of whole ration, actual weight		—	—	31·04	14·83	4·05	41·91	268
Ration Scale No. 4: Fresh meat, bread, potatoes, jam and grocery ration (55 oz.)	Fresh meat (beef), sides, medium fat, 1¼ lb.	566·80	566·80	279·99	83·88	102·59	—	1298
	Bread, 1¼ lb.	566·80	566·80	200·08	52·14	7·36	300·97	1516
	Potatoes, ½ lb.	226·80	226·80	141·97	4·08	0·22	33·32	154
	Jam, strawberry, ¼ lb.	113·40	88·60	15·45	0·61	—	68·94	285
	Sugar, 2 oz.	56·70	49·30	—	—	—	46·83†	192
	Tea, ½ oz.	14·17	19·23	1·92	—	—	—	—
	Salt (dry), ½ oz.	14·17	13·93	—	—	—	—	—
Totals		1558·84	1531·46	639·41	140·71	110·17	450·06	3445
Percentage of whole ration, actual weight		—	—	41·75	9·18	7·19	29·38	224

* On one occasion the salt contained as much as 1·874 grammes of water.

† Cane sugar (invert sugar).

D.—DIAGRAM SHOWING VARIATIONS IN WEIGHT IN TWO EXPERIMENTAL MARCHES.



E.—TABLE SHOWING RATION SCALES, SECOND EXPERIMENTAL MARCH (ARTICLES ACTUALLY ISSUED).

		Weight in Grammes.		Moisture.	Protein.	Fat.	Carbo-hydrate.	Calories.
		Nominal.	Actual.					
No. 1, issued 18th, 19th, and 20th	Preserved meat, 1 lb. (nominal)	453·60	336·00	183·28	100·59	42·50	—	808
	Biscuit, 1 lb.	453·60	484·00	35·42	75·31	6·67	361·35	1852
	Sugar, 2¼ oz.	70·90	70·90	—	—	—	63·79	261
	Jam, 4 oz.	141·70	113·40	19·77	—	—	88·24	361
	Oatmeal, 2 oz.	56·70	56·70	4·14	9·13	4·08	38·27	233
	Cheese, 2 oz.	56·70	56·70	15·53	15·71	20·86	2·32	268
	Bacon, 2 oz.	56·70	56·70	9·86	5·61	38·22	—	378
	Vegetables, 8 oz.	226·80	226·80	209·24	4·08	1·13	10·65	70
	Totals	1516·70	1401·20	477·24	210·43	113·46	564·62	4232
No. 3, issued 24th, 25th, 26th, and 27th	Fresh meat, 1¼ lb.	567·00	567·00	248·35	83·88	102·59	—	1298
	Bread, 1¼ lb.	567·00	567·00	193·25	52·14	7·36	300·97	1516
	Sugar, 2½ oz.	70·90	70·90	—	—	—	63·79	261
	Jam, 4 oz.	141·70	113·40	19·77	—	—	88·24	362
	Oatmeal, 2 oz.	56·70	56·70	4·14	9·13	4·08	38·27	233
	Bacon, 2 oz.	56·70	56·70	9·86	5·61	38·22	—	378
	Cheese, 2 oz.	56·70	56·70	15·53	15·71	20·86	2·32	268
	Vegetables, 8 oz.	113·40	113·40	209·24	3·18	0·68	20·18	102
	Totals	1630·10	1601·80	700·14	169·65	173·79	513·77	4418

Tea and salt rations as in First March.

SUMMARY OF RATION SCALES.

	Protein.	Fat.	Carbo-hydrate.	Calories.
No. 1	210·43	113·465	564·62	4232 (18th to 20th)
No. 2	201·50	181·355	576·65	4877 (21st to 23rd)
No. 3	169·65	173·795	513·77	4418 (24th to 27th)
No. 4	182·87	176·87	548·63	4645 (28th to 30th)

NET ENERGY VALUE OF ABOVE (DEDUCTING 10 PER CENT).

No. 1	3809
No. 2	4389
No. 3	3976
No. 4	4180

F.—CALCULATIONS SHOWING ESTIMATED TOTAL ENERGY EXPENDED ON SECOND EXPERIMENTAL MARCH, INTERNAL AND EXTERNAL, WITH ENERGY VALUE OF FOOD CONSUMED.

Date.	Energy Expended in Calories.			Net Value of Food Consumed in Calories.
	Internal.	External.	Total.	
17th	2750	1188·4	3938·4	3809
18th	2750	1550·9	4300·9	3809
19th	2750	1657·5	4407·5	3809
20th	2750	1397·4	4147·4	4029*
21st	2750	1159·6	3909·6	4389
22nd	2750	1739·1	4489·1	4609*
23rd	3000	Nil	3000·0	4389
24th	2750	1157·5	3907·5	3976
25th	2750	1550·9	4300·9	3976
26th	2750	1657·5	4407·5	3976
27th	2750	1397·4	4147·4	4196*
28th	3000	Nil	3000·0	4204
29th	2750	1159·6	3909·6	4424*
Totals			51865·8	53595
Average per man per day			3989·7	4122

* Rum, 2½ oz. (equivalent to 220 Calories) issued.

G.—EMERGENCY, IRON, OR RESERVE RATIONS.

RATIONS CARRIED ON THE PERSON WHICH ARE ONLY TO BE EATEN WHEN NOTHING ELSE IS AVAILABLE, AND THEN ONLY BY ORDER OF AN OFFICER.

	Number Carried on the Person.	Weight of One Ration in Grammes.		Approximate Principles.			Calories per Ration.	Authority.	Remarks.
		Net.	Gross.	Protein.	Fat.	Carbo-hydrate.			
Great Britain ..	1	184	269	59	50	64	969	—	—
France	1	766	938	127	39	327	2226	Lemoine	0·0625 gramme brandy not included.
Germany	2	650	777	91	60	239	1913	Bischoff	—
Austria	2	540	740	71	31	185	1336	Bischoff	—
Russia	2½ (only 1 meat ration)	1409	1563	141	53	539	3280	König	Calculated as one day's bread, not biscuit.
Sweden	1	758	1054	100	65	322	2338	—	—
America	1 (emergency)	227	340	57	770	79	1325	Munson	Two haversack rations may be carried.
	1 (haversack)	899	1316	97	216	395	4061		
Japan	2	721	907	—	—	—	—	Matignon	Biscuits.
		600	680	—	—	—	1993	—	Desiccated rice.
India (Native Army)	1	680	—	—	—	—	2605	—	F.S. ration biscuits.
	—	680	—	61	11	521	2489	McCay	Atta and gur.

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